



Analysis of group problem-solving tasks in a geometry course for teachers using computer-mediated conferencing

by Brian Patrick Beaudrie

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Education  
Montana State University

© Copyright by Brian Patrick Beaudrie (2000)

**Abstract:**

During spring semester 1999, the researcher conducted a study at Montana State University in the undergraduate course Modern Geometry and the concurrent graduate course, Geometry for Teachers. The purpose of this study was to determine if students participating in on-line problem-solving activities communicate differently depending upon location of the student (on campus or off campus) and whether differences in communication are related to differences in achievement.

The eighteen students were placed into four collaborative work groups consisting of four or five students each. Groups were formed heterogeneously, to help eliminate extraneous variables, and help diminish the variability among those groups caused by factors other than the treatment.

For eleven weeks, groups were assigned problem-solving tasks. These tasks were addressed collaboratively, with each student contributing ideas, responding to ideas, proposing strategies, demonstrating solutions, and summarizing and reporting their groups' findings, all on-line. Each message sent was analyzed and ranked according to the Interaction Analysis Model developed by Gunawardena, Lowe, and Anderson (1997).

It was found that the communication phase levels were independent of whether the students were on campus or off campus, and that the communication phase levels were independent of group membership. Positive correlations were found between group task rankings and number of messages sent, number of high level messages sent, and highest phase level message attained in each group task. Total messages per task decreased during the semester, and while two of the four groups significantly decreased in average communication score, only four of the eighteen individuals in the study showed a significant decrease in average communication score.

The researcher concluded that the amount and level of communication between on-line problem-solving groups were important factors in group academic achievement, and that students communication phase level was dependent upon whether the students were on campus or off campus.

ANALYSIS OF GROUP PROBLEM-SOLVING TASKS IN A GEOMETRY COURSE  
FOR TEACHERS USING COMPUTER-MEDIATED CONFERENCING

by

Brian Patrick Beaudrie

A thesis submitted in partial fulfillment  
of the requirements for the degree

of

Doctor of Education

MONTANA STATE UNIVERSITY  
Bozeman, Montana

May, 2000

© COPYRIGHT

by

Brian Patrick Beaudrie

2000

All Rights Reserved

D378

B3819

# APPROVAL

of a thesis submitted by

Brian Patrick Beaudrie

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Dr. David Thomas  
(co-chair)

David A. Thomas  
(Signature)

12 Apr 2000  
Date

Dr. William Hall  
(co-chair)

William A. Hall  
(Signature)

17 April 2000  
Date

Approved for the Department of Education

Dr. Gloria Gregg

Gloria Gregg  
(Signature)

17 April 2000  
Date

Approved for the College of Graduate Studies

Dr. Bruce McLeod

Bruce R. McLeod  
(Signature)

4-24-00  
Date

## STATEMENT OF PERMISSION TO USE

In presenting this dissertation in partial fulfillment of the requirements for a doctoral degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library. I further agree that copying of this dissertation is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for extensive copying or reproduction of this thesis should be referred to Bell & Howell Information and Learning, 300 North Zeeb Road, Ann Arbor, Michigan, 48106, to whom I have granted "the exclusive right to reproduce and distribute my dissertation in and from microform along with the non-exclusive right to reproduce and distribute any abstract in any format in whole or in part."

Signature Brian Beaudrie

Date April 11, 2000

## VITA

Brian Patrick Beaudrie was born on March 29<sup>th</sup> 1965 in Cavalier, North Dakota to Merton and Judy Beaudrie. He attended the Cavalier Public Schools, and graduated from Cavalier High School in May, 1983.

He received a Bachelor of Science in Education degree from Mayville State University in 1988 and began a teaching career as a computer instructor and coordinator for the Killdeer Public School District in Killdeer, North Dakota.

After teaching for three years, he accepted a graduate teaching assistantship in 1991 at the University of North Dakota, Grand Forks, North Dakota, and finished a Master of Science degree in Mathematics there in 1993. Following graduation, he taught as an adjunct instructor at Winona State University, Winona, Minnesota, for two years.

In 1995, he accepted a graduate teaching assistantship with the Department of Mathematical Sciences at Montana State University in Bozeman, Montana. In 1996, after teaching courses in Finite Mathematics and Mathematics for Elementary Teachers, he accepted a graduate research assistantship with the Network Montana Project. In 1997, he began working as a graduate research assistant with the NASA CERES Project. In 1999, after finishing all but the dissertation requirement for his doctoral degree in Curriculum and Instruction from the Department of Education at Montana State University, he accepted a position as an assistant professor at Northern Arizona University in Flagstaff, Arizona. In the year 2000, he completed the requirements for the Doctor of Education degree.

## ACKNOWLEDGMENTS

The writer is grateful for the help provided by many people during the completion of this study. The writer is especially grateful to Dr. David Thomas, the mathematics department chairman of his graduate committee. No other individual has contributed as much to the writer's continued work on this project. It is safe to state that without his constant encouragement, this study would have not been completed. The writer would also like to express his gratitude to the rest of his graduate committee as well: Dr. William Hall, the education department chairman of his graduate committee, Dr. Eric Strohmeyer, Dr. Theodore Hodgson and Dr. Jana Noel.

The writer would also like to acknowledge the cooperation of the staffs of three departments: the Department of Education at Montana State University-Bozeman, the Department of Mathematical Sciences at Montana State University-Bozeman, and the Department of Mathematics and Statistics at Northern Arizona University. In particular, he is especially grateful to Dr. Graydon Bell and Lia Mann of Northern Arizona University, who assisted with the statistics portion of this study.

Finally, the writer would like to acknowledge the contribution of his family; parents Merton and Judy, and siblings Tina, Dean, Michael, Alan, and Bob. Although they sometimes wonder what on earth I am doing, their support and encouragement has always been invaluable to the writer's educational endeavors.

## TABLE OF CONTENTS

|                                                                       |     |
|-----------------------------------------------------------------------|-----|
| 1. PROBLEM STATEMENT AND REVIEW OF LITERATURE.....                    | 1   |
| Introduction.....                                                     | 1   |
| Statement of the Problem.....                                         | 5   |
| On-line Communication.....                                            | 6   |
| Need for the Study.....                                               | 9   |
| Definition of Terms.....                                              | 13  |
| Questions to be Answered.....                                         | 17  |
| Review of the Literature.....                                         | 19  |
| Preliminary Comments.....                                             | 19  |
| Distance Education.....                                               | 19  |
| Non-Internet Based Distance Education.....                            | 21  |
| Distance Education using the Internet.....                            | 33  |
| Computer Use in Mathematics Education.....                            | 43  |
| Collaborative Learning using the Computer.....                        | 45  |
| Computer Anxiety, Attitudes, and Gender.....                          | 51  |
| 2. DESIGN OF THE STUDY.....                                           | 60  |
| Conceptual Framework.....                                             | 60  |
| Description of the Population.....                                    | 62  |
| Description of Treatments.....                                        | 64  |
| Methods of Data Collection.....                                       | 68  |
| Academic Achievement.....                                             | 68  |
| Communication Phase Level.....                                        | 73  |
| Computer Attitudes and Anxiety.....                                   | 79  |
| Prior Mathematical Achievement.....                                   | 80  |
| Attitudes Towards Course and Towards the Two Treatments.....          | 81  |
| Research Design.....                                                  | 81  |
| Statistical Hypotheses.....                                           | 85  |
| Analysis of Data.....                                                 | 90  |
| Limitations and Delimitations.....                                    | 92  |
| 3. DATA ANALYSIS AND FINDINGS.....                                    | 94  |
| Introduction.....                                                     | 94  |
| Communication - On campus vs. Off campus.....                         | 94  |
| Individual Achievement and On-line Communication.....                 | 98  |
| Group Achievement and On-line Communication.....                      | 101 |
| Changes in On-line Communication Patterns among Groups Over Time..... | 103 |

## TABLE OF CONTENTS - CONTINUED

|                                                                            |         |
|----------------------------------------------------------------------------|---------|
| Changes in On-line Communication Patterns among Individuals Over Time..... | 113     |
| Gender Differences in On-line Communication.....                           | 121     |
| Gender Differences in Individual Achievement .....                         | 126     |
| Incomplete Data Sets.....                                                  | 127     |
| Computer Attitudes and Anxiety.....                                        | 127     |
| Attitudes Towards Course.....                                              | 130     |
| Summary.....                                                               | 133     |
| <br>4. CONCLUSIONS.....                                                    | <br>135 |
| Introduction.....                                                          | 135     |
| Summary of the Study.....                                                  | 135     |
| Conclusions and Implications.....                                          | 139     |
| Discussion and Observations.....                                           | 147     |
| Recommendations for Further Action.....                                    | 151     |
| Recommendations for Further Study.....                                     | 153     |
| <br>REFERENCES CITED.....                                                  | <br>157 |
| <br>APPENDICES.....                                                        | <br>164 |
| APPENDIX A: THE INSTRUMENTS.....                                           | 165     |
| APPENDIX B: THE GROUP TASKS.....                                           | 174     |
| APPENDIX C: THE COURSE SYLLABUS.....                                       | 188     |
| APPENDIX D: CRITERIA USED TO RANK GROUP TASKS.....                         | 195     |
| APPENDIX E: EXAMPLE GROUP PROBLEM-SOLVING TASKS.....                       | 201     |
| APPENDIX F: DATA TABLES .....                                              | 219     |
| APPENDIX G: PERMISSION FORMS.....                                          | 223     |

## LIST OF TABLES

| Table                                                                                  | Page |
|----------------------------------------------------------------------------------------|------|
| 1. Total messages scored at each phase level.....                                      | 95   |
| 2. Expected values for messages scored at each phase level.....                        | 95   |
| 3. Number of messages scored at each phase level for each group.....                   | 97   |
| 4. Expected values of number of messages scored for each group.....                    | 97   |
| 5. Average communication score by task.....                                            | 104  |
| 6. Number of messages per task sent by each group.....                                 | 106  |
| 7. Total number of high level messages per task for each group.....                    | 108  |
| 8. Percentage of high level messages per task for each group.....                      | 110  |
| 9. Highest message level attained on each task by each group.....                      | 112  |
| 10. Individual Red Group member's average communication score for each task.....       | 113  |
| 11. Individual Blue Group member's average communication score for each task.....      | 115  |
| 12. Individual Green Group member's average<br>communication score for each task.....  | 117  |
| 13. Individual Yellow Group member's<br>average communication score for each task..... | 119  |
| 14. ANOVA for total number of scored messages by gender.....                           | 122  |
| 15. ANOVA for average communication score by gender.....                               | 123  |
| 16. ANOVA for high level messages by gender.....                                       | 124  |
| 17. ANOVA for percentage of high level messages by gender.....                         | 124  |
| 18. Number of messages at each phase level for each gender.....                        | 125  |

## LIST OF TABLES

| Table                                                                    | Page |
|--------------------------------------------------------------------------|------|
| 19. Expected number of messages at each phase level for each gender..... | 125  |
| 20. ANOVA for mean test score by gender.....                             | 126  |
| 21. ANOVA for final test scores by gender.....                           | 127  |
| 22. Mean score from each question.....                                   | 131  |
| 23. Results from survey of student's attitudes about the course.....     | 133  |
| 24. Group task scores.....                                               | 220  |
| 25. Ranking of group tasks.....                                          | 221  |
| 26. Computer Attitude Scale survey results.....                          | 221  |
| 27. Individual and group message data.....                               | 222  |

## LIST OF FIGURES

| Figure                                                                                | Page |
|---------------------------------------------------------------------------------------|------|
| 1. Average communication score by task.....                                           | 104  |
| 2. Number of messages per task sent by each group.....                                | 106  |
| 3. Total number of high level messages per task for each group.....                   | 108  |
| 4. Percentage of high level messages per task for each group.....                     | 110  |
| 5. Highest message level attained on each task by each group.....                     | 112  |
| 6. Individual Red Group member's average communication score for each task....        | 114  |
| 7. Individual Blue Group member's average communication score for each task...        | 116  |
| 8. Individual Green Group member's<br>average communication score for each task.....  | 118  |
| 9. Individual Yellow Group member's<br>average communication score for each task..... | 120  |

## ABSTRACT

During spring semester 1999, the researcher conducted a study at Montana State University in the undergraduate course Modern Geometry and the concurrent graduate course, Geometry for Teachers. The purpose of this study was to determine if students participating in on-line problem-solving activities communicate differently depending upon location of the student (on campus or off campus) and whether differences in communication are related to differences in achievement.

The eighteen students were placed into four collaborative work groups consisting of four or five students each. Groups were formed heterogeneously, to help eliminate extraneous variables, and help diminish the variability among those groups caused by factors other than the treatment.

For eleven weeks, groups were assigned problem-solving tasks. These tasks were addressed collaboratively, with each student contributing ideas, responding to ideas, proposing strategies, demonstrating solutions, and summarizing and reporting their groups' findings, all on-line. Each message sent was analyzed and ranked according to the Interaction Analysis Model developed by Gunawardena, Lowe, and Anderson (1997).

It was found that the communication phase levels were independent of whether the students were on campus or off campus, and that the communication phase levels were independent of group membership. Positive correlations were found between group task rankings and number of messages sent, number of high level messages sent, and highest phase level message attained in each group task. Total messages per task decreased during the semester, and while two of the four groups significantly decreased in average communication score, only four of the eighteen individuals in the study showed a significant decrease in average communication score.

The researcher concluded that the amount and level of communication between on-line problem-solving groups were important factors in group academic achievement, and that students communication phase level was dependent upon whether the students were on campus or off campus.

## CHAPTER 1

### PROBLEM STATEMENT AND REVIEW OF LITERATURE

#### Introduction

Since the late 1970's, the use of technology in the classroom has been increasing at an almost exponential rate. The use of computers and calculators is so prevalent in the modern classroom that it is scarcely given a second thought, whereas twenty years ago the very idea was practically unthinkable. In that short time frame, educators and parents have gone from asking themselves whether calculators and computers should be in the classrooms at all to how they may be best used to maximize the learning potential of students.

In the publication "Curriculum and Evaluation Standards for School Mathematics," the National Council of Teachers of Mathematics (1989) stressed the increased use of technology in the classroom at all grade levels. The NCTM also emphasized that students should have access to a computer at all times in their classroom, and that each school should have some type of computer laboratory facility to allow whole groups or classes to work on computers at the same time.

However, the uses of computers in the classroom have changed since the publication of the NCTM Standards. At the time of its publication, the primary use of computers in the middle school and high school centered on learning and using programming languages. Of secondary importance at these levels was the use of specialized drill and practice software. Gradually, the focus began to change from

programming to learning the use of applications software, such as spreadsheets, data bases, word processing, and the like. While all of these components are still an important and integral part of the computer curriculum, a new use of the computer for educational purposes has emerged: the use of the Internet and the World Wide Web (WWW) to deliver courses into the computer labs, classrooms, and even the homes of learners everywhere.

The use of the Internet and WWW is increasingly a part of everyday life. Eddy and Spaulding (1996) estimated that in 1994, there were twenty million users of the Internet across the world, and that the growth rate was approximately one million users per month. Even this staggering growth figure proved to be an underestimate. In 1999 the number of users worldwide was estimated at 157 million people; by the end of the year 2000, an estimated 320 million people will be using the Internet for browsing or e-mail services (Euro-Marketing Associates, 1999).

State governments are beginning to invest heavily in the development of distance education in their states. West (1995) reported that the state of Delaware planned to spend thirty million dollars to build a fiber optic telecommunications network that within the next two years will electronically link every student and teacher in every one of its 7,000 public school classrooms. In Iowa, a total of eighteen million dollars has been approved for the state to begin the exact same project. According to West, several other states are beginning the process to build state networks for education as well.

The federal government has also become involved. E-Rate, or the Universal Service Fund, was created by the FCC Telecommunications Act of 1996. This 2.5 billion

dollar fund was used by schools and libraries to help defer costs associated with accessing the Internet. All schools and libraries in the United States qualify for E-Rate funds.

Business and industry are also seeing the value of having distance education in the schools. In California, West (1996) reported about NetDay 96, a grassroots effort to prepare the schools within the state for access to the Internet. The project, funded mostly by corporate donations, laid more than six million feet of cable in roughly 5,000 California schools. Over 20,000 volunteers, including President Bill Clinton and Vice President Al Gore, participated in the effort. NetDay has now evolved into a national effort, with the eventual goal of having a NetDay in each of the 50 states.

It is obvious that the excitement concerning the possibilities of conducting distance education classes through Cyberspace is real, and growing. But also growing are certain questions regarding its use. These questions include "What exactly is distance education? How does it work using the Internet? What are the advantages and disadvantages of teaching students with such a medium as opposed to other, more traditional forms of education? And what is the best way to conduct classes over the Internet?"

According to Willis (1995), at its most basic level, distance education takes place when a teacher and student(s) are separated by physical distance, and technology (i.e. voice, video, data, and print) is/are used to bridge the instructional gap. This definition would seem to encompass the use of interactive television (ITV) and video courses, and even mail correspondence courses.

There are several ways that distance education can "work" using the Internet. Some distance education courses offered via the Internet differ from the old-style correspondence courses or from ITV in delivery medium only. However, these are in the minority. Other courses are much more interactive in their use of Cyberspace. Slater, Beaudrie and Fixen (1998) pointed to several very recent projects, including the Network Montana Project, Shodor Educational Foundation Program, and the Earth System Science Community Project, in which hypermediated instructional units (units whose content is entirely on the Internet) were being developed that require students to access Internet-based resources. In other words, students enrolled in these courses are using the Internet almost exclusively to conduct their research, find the necessary materials, solve problems, and complete assignments. The Internet is also used as a means of communication between the instructor and the other students in the course through the use of e-mail, bulletin boards, chat rooms, and even direct visual and/or audio communication (although at the present time, this is a rarity). Beaudrie, Caditz, Slater, and Stephenson (1998) wrote about Webquests, first introduced by Dodge and March at San Diego State University (Dodge, 1995, 1997). Simply put, a WebQuest is a structured, inquiry-based activity in which students are asked to use Internet resources to gather information they need to complete an assignment. One key element of a WebQuest is that many of the resources needed to complete the quest are embedded in the WebQuest activity itself as hyperlinks. These links might include web documents, experts available via e-mail or real-time conferencing, searchable databases on the net, and books and other documents physically available in the learner's setting.

### **Statement of the Problem**

This study investigated differences in the quantity and level of communications occurring in a geometry course for teachers where group problem-solving activities were worked and discussed in an Internet-based, distance education format. This course was designed primarily for pre-service and in-service secondary school mathematics teachers.

A rubric developed by Gunawardena, Lowe, and Anderson (1997) to characterize and rank individual communications in on-line group discussions was used to analyze the contributions made by the participants in the problem-solving activities. The rubric divided on-line communication into five hierarchical phase levels. A copy of this instrument can be found in Appendix A.

The central question answered in this study was whether students participating in on-line problem-solving activities communicated differently depending upon the location of the student (on campus or off campus) and whether differences in amount and phase level of the communication were related to differences in achievement. In other words, the problem of this study was to determine if there was a significant difference in on-line communication between on-campus and off-campus students, and how differences in communication related to academic achievement for students performing group problem-solving activities online in a geometry class for teachers.

The dependent variables were the scores earned by each group on all problem-solving activities, and the scores earned by each individual on the final test and their overall test average. One independent variable was the phase level score of each message. This was used to calculate the average communication score of each group and

individual per task, the number of messages sent by each group and individual per task, the number of high level messages sent by each group and individual per task, the percentage of high level messages sent by each group and individual per task, and the highest attained level of communication for each group for each task. The average communication score was calculated by dividing the total scores on all of the messages for a group or an individual by the number of scored messages that group or individual had sent. High level messages, defined by Gunawardena, Lowe, and Anderson (1997), are messages that are scored at phase levels three, four, or five. The percentage of high level messages for each group was calculated by dividing the total number of high level messages by the total number of messages for that group. Other independent variables include the gender of the students, and each student's comfort level with technology. The study was conducted during the Spring Semester of 1999 at Montana State University.

### **On-line Communication**

The students engaged in a series of on-line, small group, problem-solving activities on-line using the software First Class Client (URL: <http://www.softarc.com>), an Internet-based communications software tool used in many distance courses taught at Montana State University. First Class Client has several valuable features when conducting an on-line course. It allows students to attach files created using other software tools, such as the Geometer's Sketchpad or Microsoft Word to messages posted on the bulletin board. This feature proved to be a valuable asset as the students discussed their problem-solving tasks.

First Class Client allows students to communicate in an asynchronous communication environment through the use of a bulletin board, or a synchronous communication environment through the use of a chat room. In asynchronous communication, people do not have to be logged on to the system at the same time. Asynchronicity frees students and teachers from the constraints of both time and space. According to Harasim (1990) and McComb (1993), there are several advantages to using asynchronous communication as a form of communication in computer-mediated communication.

One advantage lies in the convenience of use. Students participating in a course taking place in an asynchronous communication environment do not have to wait until class or office hours to ask questions of the instructor. Similarly, students do not have to wait until they can meet face to face, or wait until they can call each other via telephone to communicate with each other. Students can ask and respond to questions whenever they wish, rather than either having to quickly think of a solution, or remember a solution until they meet the professor or classmate who asked the question. This can lead to greater interaction among students, and between students and instructor.

Another advantage is the ability to communicate directly with a particular subgroup of the class. Instructors and students can respond to individual or small group queries without taking up class time. A third advantage to asynchronous communication is that course communication is determined principally by the students rather than by the instructor. Making students responsible for their own learning of materials, as opposed to an instructor lecturing in an enclosed classroom at a specific time, empowers the students

to take charge of their own learning. There is less passivity among the students of distance learning courses (Harasim, 1990, and McComb, 1993).

The final benefit of asynchronous communication (according to Harasim and McComb) is the need to communicate in writing. Written communication, when compared to spoken communication, encourages deeper thought and a more clear articulation of ideas by students to the instructor and to each other. The fact that most on-line communication is stored permanently in the computer system also plays a role in students wishing to be very clear and careful in their responses.

How does synchronous communication via a chat room differ from asynchronous communication? Synchronous communication has several of the same advantages as asynchronous: the ability to communicate with or among a subgroup or an individual; the students must take more responsibility for their education, with the instructor in a supporting role; and the students must communicate in writing. The major difference lies in the convenience factor. If students use a chat room, they must all be present on the computer system at the same time. While this difference may not account for differences in communication level, a by-product of it may: the wait time, or time between question and response. When using a chat room, students may respond almost instantaneously to queries, and may not put as complete a thought process into their responses as they would when communicating asynchronously. However, an advantage to the use of synchronous communication is its relative similarity (when compared to asynchronous communication) to face-to-face discussions with the instructor or other students.

### Need for the Study

Although the use of the Internet to conduct courses is a practice that continues to grow rapidly, the study of the use of the Internet as a medium to conduct distance learning is in its infancy. The reasons for this growth, particularly at the university level, reflect the evolution of higher education in general. The Virginia Commission on the University of the Twenty First Century reported that higher education is evolving as follows (Potter and Chickering, 1991):

- The college will be a network of resources, not a place.
- Offerings will give students a global, multicultural perspective.
- Widespread use of new technologies will improve the quality of instruction, increase contact between students and faculty, and reduce time, place, and space constraints.
- Living and learning will be more closely integrated outside the classroom.

These findings illustrate the slow, yet fundamental changes that are occurring in electronically distributed distance education courses at colleges and universities across the country. As this change in the delivery of instruction overtakes these usually slow changing institutions, thought needs to be given to the role of distance education via the Internet. There are several questions about this role that need answers. One issue that is often overlooked is the role communication between students plays in the effectiveness of learning in a distance learning course. As reported by Bober (1998), it has been argued that the level and type of student interactions are critical predictors of the success or failure of an on-line course. This argument, however, has not been formally tested.

The reasons that universities and colleges are using distance education with increasing frequency are pointed out by Harasim (1990), McComb (1993), and Seagren and Watwood (1996). Among them:

- Students and instructors do not have to be in the same place, or meet at the same time. Online education can be available any hour of the day or night, seven days a week.
- Students can communicate easily with one another, thus promoting the possibility of collaborative learning.
- Students anywhere in the world can be part of a single class. Teachers anywhere in the world can team-teach a course.
- The computer provides specialized communication that can actually improve what is done face to face in courses.
- This type of technology is less expensive than telephone, interactive television, or video conferencing for providing communications.

These reasons, along with several others (such as meeting the educational demands of different groups of students) are among those that explain why in 1997, nearly 400 accredited colleges and universities in North America employed online instruction of some sort (Velsmid, 1997). In addition, there were over 150 accredited institutions that offered entire bachelor's degree programs to students who never, or rarely, visited the campus (Herther, 1997). By 2002, it is estimated that 85 percent of two-year and 84 percent of four-year institutions will offer distance education courses (Council for Higher Education Accreditation, 1999). With so many colleges and

universities jumping on the distance learning via WWW/Internet bandwagon, studies that determine the most effective ways to offer these classes are a necessity for the success of both the university and the student.

Although the body of knowledge about Internet education has grown in recent years, a vast majority of what has been written about distance learning consists of opinion pieces, how-to articles, surveys, case studies, and second-hand reports that do not include original research. There is a relative dearth of original research dedicated to explaining or predicting events related to distance learning (Merisotis and Phipps, 1999). Those studies that are research studies are usually concerned with the effects on learning in a distance learning course. Few studies focus on the communication aspects of the environment, how these aspects may affect learning, the attitudes of the learners participating in such an environment, or on the drawbacks or unforeseen difficulties that the communication environment may produce. Also, in most of the studies on distance learning classes via the Internet, the communication method has been asynchronous, either strictly through e-mail or by some type of bulletin board system (Cheng, Lehman, and Armstrong, 1991; Hiltz, 1993; McComb, 1993; Wesley and Franks, 1995; Gunawardena, Lowe, and Anderson, 1997). The major reason for the focus on asynchronous communication is the fact that until recently, synchronous communication was simply not a realistic possibility in most distance education situations. In recent years, there has been a tremendous push to use synchronous communication as the major or sole method of communication for students in distance education classes. According to popular theory, the major justification for this push is that synchronous communication

represents the latest technological advancement. Another factor in the push is the thought that it is more convenient for both students and teachers to use when compared to using a bulletin board or e-mail to conduct communications. Part of the logic behind that thought may be due to the fact that synchronous communication is closer in communication style to traditional classes than asynchronous communication.

In their recent study, Gunawardena, Lowe and Anderson (1997), made note of several areas in which further study is needed in regards to the use of their Interaction Analysis Model. They believe that the model would be appropriate for use in the evaluation of Computer Mediated Conferencing (CMC) which has a moderator of greater skill than most participants, as in the teacher and his or her students in a classroom. They do note that the instructor of such a class must be open to conceptualizing the learning process based on the philosophy of constructivism.

The very fact that there exists a lack of research in print on this topic justifies the importance of such a study. Eddy (1996) pointed out that there are literally millions of people taking distance learning courses. The Council for Higher Education Accreditation reported that by the year 2002, more than two million students will be enrolled in distance education courses (CHEA, 1999). It does not require much of a stretch of the imagination to believe that millions more may be contemplating such a move. Without studies of this nature, many people may be making a choice that is not the most appropriate for their situation. In addition, studies on distance learning will help those who offer such courses to design them in such a fashion to allow the courses to be more effective.

### Definition of Terms

Several of these terms have been gathered from on-line dictionaries that are specific to topics of computer technology and distance education. The abbreviation FOLDOC refers to the Free On-Line Dictionary Of Computing (URL: <http://wombat.doc.ic.ac.uk/foldoc/index.html>) created by Dennis Howe (1993). There exists a mirror site in the United States (URL: <http://www.instantweb.com/foldoc>). The Internet Glossary (URL: <http://ccmail.sunysb.edu/INTGLOS.HTM>), abbreviated IG, is located at the State University of New York at Stony Brook (1998).

- Asynchronous Communication: for the purposes of this study, it will be on-line communication that takes place through the use of a bulletin board messaging system.
- Browser (IG): A software program that allows the user to retrieve, display, and read information on the World Wide Web. Resulting screens contain images, colors, and other graphics. Three well-known browsers are Netscape, Internet Explorer, and Mosaic.
- Bulletin Board System (FOLDOC): A computer and associated software which typically provides an electronic message database where people can log in and leave messages. Messages are typically split into topic groups. Any user may submit or read any message in these public areas. A Bulletin Board System may also provide archives of files, personal e-mail and any other services or activities of interest to the bulletin board's system operator. Also known as a BBS.

- Chat System (FOLDOC): A system that allows any number of logged-in users to have a typed, real-time, on-line conversation, either by all users logging into the same computer, or more commonly nowadays, via a network. Also known as a Chat Room.
- Computer Conferencing (Gunawardena, Lowe, and Anderson, 1997): The exchange of messages among a group of participants by means of networked computers, for the purpose of discussing a topic of mutual interest. Also known as Computer-Mediated Conferencing or CMC.
- Cyberspace (IG): A term synonymous with Internet and World Wide Web.
- Distance Education (Grimes, 1993): Any formal approach to learning in which the majority of the instruction occurs while the educator and learner are at a distance from each other. The United States Distance Learning Association defines distance learning as the acquisition of knowledge and skills through mediated information and instruction, encompassing all technologies and other forms of learning at a distance.
- E-mail (FOLDOC): Electronic mail. Messages automatically passed from one computer user to another, often through computer networks and/or via modems over telephone lines.
- Group-Mediated Cognition or GMC (Smith, 1994): The situated form of thinking in which the thinking of each individual is influenced by the thinking of the other members taking part in the discussion, even if only to

disagree. In other words, the situation itself (the group meeting) exerts a strong mediating effect on individual cognitive and conceptual processes.

- Home Page (IG): The first page (or welcome page) of a Web site.
- Hypermedia (Hughes, 1997): Hypermedia is an acronym which combines the words hypertext and multimedia. It refers to the electronic presentation of information in the form of plain text as well as other forms, such as graphics, sound, animation, and/or video.
- Hypertext (Nelson, 1967): A combination of natural language text with the computer's capacity for interactive branching or dynamic display of a nonlinear text which cannot be printed on a conventional page. Note: Hypertext refers to text that is linked, while hypermedia can include graphics, video, sound, etc., which are linked. However, the words hypermedia and hypertext are often used as synonyms.
- Hypertext Navigation (IG): Moving from one word or image in a Web document directly to another document because of a hyperlinked connection between the two. Within a document, hyperlinked words or images are usually underlined or highlighted in a color different from the rest of the text.
- Hypertext Markup Language or HTML (FOLDOC): The major Hypertext document format used on the World Wide Web, used for creating World Wide Web pages.

- Hypermediated Lesson (Slater, Beaudrie, and Fixen, 1998): Instructional units whose content, research base, problems, and other materials are mostly or entirely on the Internet. Also known as Internet-based instruction.
- Interaction (Gunawardena, Lowe, and Anderson, 1997): a) The totality of interconnected and mutually responsive messages which make up a CMC. b) The entire gestalt formed by the online communications among the participants.
- internet (FOLDOC): Any set interconnected computers or computer networks interconnected with routers. The Internet is the biggest example of an internet.
- Internet (FOLDOC): The Internet is the largest internet in the world. It is a three level hierarchy composed of backbone networks (e.g. ARPAnet, NSFNet, MILNET), mid-level networks, and stub networks. These include commercial (.com or .co), university (.ac or .edu) and other research networks (.org, .net) and military (.mil) networks and span many different physical networks around the world with various protocols including the Internet Protocol.
- Internet-based Instruction: see Hypermediated Lesson.
- Multi-media (IG): Having more than one form of presentation. For example, on the Web the following media can all be used: print, pictures, drawings, movies, and sound.

- Network (IG): An electronic linking together of a number of computers. A network can be housed in one room or one building (a Local Area Network, or LAN), or be connected over great distances (like the Internet).
- URL (University at Stony Brook): An address for a file or location on the Internet. Stands for *Uniform Resource Locator*. For example, Montana State University's URL for its home page is <http://www.montana.edu>.
- Synchronous Communication: on-line communication that takes place using a chat system (chat room).
- Web Site (IG): A place on the Internet where electronic information can be accessed through the World Wide Web. A home page is an example of a Web Site.
- World Wide Web or WWW (Willis, 1995): A graphical hypertext-based Internet tool that provides access to home pages created by individuals, businesses, and other organizations. Also known as "The Web." Note: Although the definitions are different, the terms "Internet" and "World Wide Web" are often used as synonyms.

### **Questions to be Answered**

As related in the Statement of the Problem, this research determined whether there was a significant difference in communication phase levels between on-campus and off-campus problem-solving groups, and how differences in communication related to academic achievement for students performing group problem-solving tasks online in a

geometry class for teachers. The specific design for the research questions will be clearly delineated in Chapter Two.

Questions that were answered in this study are as follows:

1. Did communication occur at similar or different phase levels when comparing the on campus groups to the completely off-campus group?
2. Was individual achievement in problem-solving related to the on-line communication phase level of the individual?
3. Was group achievement in problem-solving related to the on-line communication phase level of the group?
4. Did problem-solving groups change communication levels (phases) over time?
5. Did individual students change communication levels (phases) over time?
6. Was there a difference in communication phase level between male students and female students?
7. Was there a difference in achievement between male and female students in a distance learning course?
8. Was the on-line communication level of the individual related to the comfort level and attitude of the individual in using computers?
9. Was the academic achievement of the individual in problem-solving related to the comfort level and attitude of the individual towards using computers?

## **Review of the Literature**

### **Preliminary Comments**

The purpose of this study was to determine if there are significant differences in student academic achievement and communication phase levels for students performing group problem-solving activities on-line in a college level Geometry course. The current literature presents numerous articles and studies that have focused on the topics of distance education, mathematics education, education using computers, and cooperative learning groups. This review contains research and documentation relative to the recent development and trends in all of these areas.

### **Distance Education**

The term "Distance Education" basically means any formal approach to learning in which the majority of the instruction occurs while the educator and learner are at a distance from each other. Given this definition, distance education has been occurring for several decades. Correspondence courses fall into this category, as do all of the following: Interactive and/or Instructional Television (ITV), Interactive Video, and Television programs designed to educate.

In the 1840's Sir Issac Pittman, the English inventor of shorthand, came up with the idea of the correspondence course by mail. Within a few decades, these types of programs were available in several countries, including the United States (Matthews, 1999).

In 1969 Great Britain started the Open University, which first used the mixed media approach in the form of written correspondence combined with audio and video materials, to conduct distance learning. The OU and other open universities which soon sprang up began to change the way educators viewed distance learning, effectively bringing it closer to the mainstream of higher education (Matthews, 1999).

Distance education involving the use of computer technology first appeared in the 1960's, according to Harasim (1990). Douglas Engelbart developed a system called Augment. Augment had three defining characteristics: an emphasis on providing tools to support collaborative knowledge work, an emphasis on people doing this work in an asynchronous, geographically distributed manner, and enabling idea structuring as well as idea sharing employing a hierarchical structure.

In the early 1960's Theodore Nelson was the first to use the term *hypertext* to refer to online writing and reading. In a project called Xanadu, Nelson designed an experimental self-networking system that permitted users to view hypertext libraries, create and manipulate text and graphics, send and receive messages, and structure information intuitively (Harasim, 1990).

Computer conferencing, the direct ancestor of on-line education, was invented by Murray Turoff in 1970. Turoff designed the computer conferencing environment so that it would use the computer to structure human communication for information exchange and effective problem solving. Computer conferencing has been used extensively since then, first by the United States government, then by the scientific community and the

corporate business sector, and most recently has woven its way into the educational community (Harasim, 1990).

### **Non-Internet Based Distance Education**

While this researcher is primarily concerned with distance learning involving computer networks, interactive video and television share some characteristics in common with on-line education. Some distance learning courses have been designed that take advantage of both computer networks (using e-mail and/or bulletin board system) and television to help teach the class. To start this review, five studies involving distance learning through the use of interactive television or some similar medium, with or without a computer network component, are examined first.

Hornik (1974) documented the findings of a quasi-experimental study done in El Salvador on the effects of introducing interactive television (ITV) into the classroom. The author noted that similar studies had already been done in the U.S., showing little change. Despite this, he wished to see if the results would hold true under a different setting.

The sample in Hornik's study consisted originally of 29 classes of students who began seventh grade in 1970 and finished ninth grade in 1972. The schools were located in both urban and rural areas, and in communities of differing development and wealth. Fifteen classes would receive the treatment, i.e., receive ITV in their classrooms. Another 11 would act as a control group, learning the same materials, but under a traditional format. Three schools were eliminated from the study, since they had ITV before the study began.

Three types of variables were examined. One, an achievement variable, was based upon five standardized tests given three times during the course of the study: at the beginning of seventh grade, at the beginning of eighth grade, and at the end of the ninth grade. The tests covered mathematics, social studies, science, reading, and general ability. The scores from each battery of tests were separately averaged to arrive at a cognitive skills score for each classroom. Another variable under study involved the personal and family backgrounds of the students in each classroom. The categories for this variable included wealth, education of the parents, age of students, and percentage of students who had repeated a grade. The third variable examined was based upon the characteristics of each school and community where the students lived. Factors such as school facilities, size, and physical condition were considered, in addition to community factors such as ease of access to a large city, educational availability, and various city and community resources.

Results showed that when the students entered the seventh grade, 75 percent of the variance in cognitive skills (using multiple  $r$  squared) could be predicted from the students' background and social variables. When the students left ninth grade, this score dropped to 66 percent. This is in contrast to the studies in the U. S., which showed that the role of background factors increase in predictive ability as the years of schooling increase.

The major factor in this change was found to be the use of ITV. At the beginning of the study, all classrooms were ranked; the classroom with the highest average cognitive score received a rank of 1, the second highest a rank of 2, and so on through

number 26. When the study began, the ITV and non-ITV classrooms had virtually identical mean ranks: 13.53 for the ITV classrooms, and 13.45 for the non-ITV classrooms.. By the end of the study, the mean rank for the ITV classrooms was 10.1, for the non-ITV classrooms 18.2. This change was statistically significant at  $p < .02$  using a Mann Whitney U test. Eleven of the fifteen ITV classes moved up in rank; by contrast, only 2 of the eleven non-ITV classes moved similarly. It was also noted that by the end of the ninth grade, none of the other social, personal, and community variables was a better predictor of change on the cognitive skills over the three grades than the introduction of ITV. In fact, it was the only variable that was a significant predictor of a positive nature for cognitive skills change ( $p < .05$ ).

Hornik concluded the study by citing several reasons why the study done in El Salvador produced such drastically different results than the studies completed in the United States. One reason given is the nature of the studies. The U. S. studies were large surveys, one shot cross-sectional investigations of several schools. In contrast, the El Salvador study was a three-year study of a small sample of schools. Also, the respective starting points of the students in the two schools, and the respective starting points of the school systems themselves may have been a factor. In addition, it was noted that the studies completed in the United States lumped together a wide variety of quantitatively equal but qualitatively different educational expenditures, including ITV, and found that on the average, they were all largely ineffective. However, the El Salvador study examined only one type of investment, and found that ITV did make a significant difference in lowering the mean ranks of those classrooms using it.

Cennamo, Savenye, and Smith (1990) conducted a study to investigate the perceptions of learners relative to three different educational media: interactive video (IV), instructional television (ITV) and television (TV). The study also compared treatment groups on the perceptions of learners relative to the invested mental effort when viewing the material, and achievement tests based upon tests of recall and inference.

The independent variable for the study was the method of instruction. The students who received the IV treatment were provided with practice questions that required an active response. The students who received the ITV treatment were provided with questions that required a covert response. The students who received the TV treatment were provided with no practice. The dependent variables in the study were the ratings of the students with regard to perceived effort, recall scores, and inference scores.

The sample consisted of 78 undergraduate students randomly assigned to the three treatments. Because of attrition, by the end of the study there were 25 students in the IV group, 25 in the ITV group, and 23 in the TV group.

At the beginning of the study, a questionnaire was administered to assess the preconceived notions of the students relative to difficulty of ITV, TV, and IV instruction. In this survey used by Salomon (1984), students responded to each item using a five point Likert scale. After completing the materials, the students were then given a six-question survey that asked them to estimate the amount of mental effort they had used in processing the lesson. This questionnaire also used a five-point scale. To measure the achievement variables, another questionnaire was administered that measured the

amount of recall and inferences each student had gained by watching the lesson. The recall portion consisted of 8 essay type questions designed to elicit specific responses; the inference portion featured more open-ended questions.

A repeated measures analysis of variance (ANOVA) was applied to the questionnaire on preconceptions. Results showed that there existed a significant difference in the preconceptions of the learners with regard to the difficulty of IV, ITV, and TV lesson, at  $p < .01$ . A Tukey's HSD indicated that the learners believed it was significantly easier to learn from IV than from either TV or ITV; and significantly easier to learn from ITV than TV. The p-value for the Tukey's was .05. The ANOVA performed on the perceived mental effort questionnaire revealed that there existed no significant difference between the learners perceived mental effort ( $p = .51$ ).

On the achievement variables, the ANOVA performed on the mean inference scores indicated no significant difference among the three groups. However, the ANOVA performed on the mean recall scores found a significant difference. A Tukey's HSD showed that the learners who received the IV lesson recalled significantly more information than did the learners who received the TV lesson. There was no significant difference between the mean score of the learners in the ITV group when compared to the other two groups.

The authors found several items of interest from this study. In general, if the perception of the learner was that a medium was more difficult to learn from, then scores on the inference and recall tests tended to be lower; sometimes the difference was statistically significant, and other times it was not. The fact that there existed no

significant difference in perceived mental effort was attributed partially to the limitations of the measurement instrument. Also, the fact that IV treatment learners scored highest on recall, followed by ITV and then the TV treatment groups, was not surprising given the fact that the IV group was provided with direct practice towards the recall test.

The authors concluded that the study supports the practice of including questions that require an active response in any interactive video setting. However, since these questions did not help make a significant difference in the inference test scores, perhaps some higher level questions ought to be added. The results also suggest that more research needs to be done in the following areas: to the effects of actively and covertly responding to questions; on the ways that different media are perceived by students; and on examining learners' preconceptions of media, and the ways that these preconceptions can be modified to result in increased mental effort where necessary.

Smith and McNelis (1993) conducted of a study to determine how distance education effects both academic performance and student attitude. A secondary purpose was to find possible explanations for differences in performance and attitudes of students in the host class (on campus) and those in the remote class, if any differences did indeed exist.

The sample consisted of 53 students in three sections of the same graduate level course, a required course for all of the students. Twenty-five students were in the host class, located at a large urban university. Sixteen of the students were in the remote class, located 90 miles away at a community college. The remaining 12 students were in a separate class at the university, and were taught the class in the traditional lecture

method. These students were used as a control group. The content of all three classes was identical. All of the students in each group were aware of the format of the class before they registered.

Using video technology, the instructor was able to teach the host class and the remote class simultaneously and interactively. Monitors allowed the teacher to view the remote class while teaching. Also, FAX machines and computer mail were employed to provide additional ways for teacher and students to communicate.

To determine if there was any difference in academic outcomes, the final grades from the three sections were analyzed using an Analysis of Variance (ANOVA), and Scheffe's test, when necessary. The grade point averages (GPA) of the students subsequent to entering the class were also analyzed to determine if there were any preexisting differences. To determine affective factors, the students completed course surveys. In addition, students were allowed to express their concerns about the distance education course at the beginning, middle, and end of the semester.

Results of the ANOVA showed no significant differences among the three groups for prior GPA, meaning all three groups were statistically equivalent before taking the course. An ANOVA and a follow up Scheffe's on the final grade showed that the average for the host class (2.72) was significantly lower than the control group (3.50) with a p-value of .01. However, there existed no significant difference in final grade average between the remote class (3.12) and the control group, or between the remote class and the host class.

The surveys indicated that 8 of the 25 students in the host class had a negative opinion towards the use of distance education; only 3 of the 16 in the remote class felt similarly. The rest of the students in both groups were either neutral, or had a positive opinion towards the technology. Most of the negative feedback focused on the limitations or distractions of the equipment. There were also several complaints, mostly from the host class, of having to "share" the instructor with the other site. In all, most students still believed in the use of distance education; they just favored the traditional method of delivery.

The authors concluded by stating that the achievement data were inconclusive. They believed that the most probable explanation for the poor showing of the host class was a negative attitude towards the technology, not a direct result of the technology itself. They also believed that the sample size was too small to draw any definite conclusions. The authors conclude by reiterating that research into distance education is extremely limited at this juncture, and that they will continue to closely monitor the attitudes and achievement of distance education students in the future.

McHenry and Bozik (1995) reported the results of a qualitative study designed to explore the communication interaction that took place in an interactive television (ITV) college classroom. In particular, the authors wished to discover what the points of view of the students were about learning and participating in the ITV classroom.

The sample size consisted of 27 students, 19 of who were taught at the main, or origination site, an Iowa community college. The other eight were located at four remote classrooms in nearby high schools, known as receive sites. Of these, all were non-

traditional students, meaning they were all 24 years of age or older. Two of the receive sites had three students apiece, with the other two having a single student. Twenty of the students were female.

The instructor taught using a microphone attached to his lapel, 3 cameras, and a touch screen computer. The computer allowed him to display what was being shown on two monitors located at each of the remote sites. All students had microphones, which when used properly allowed them to be heard at all sites and override the instructor's microphone.

The authors attempted to answer the following three questions:

- 1) What are the influences on the communication that takes place between the students and between the students and the teacher?
- 2) How does technology affect the interaction in the classroom?
- 3) Does the distance separating the teacher and students have any other affects on communication in or between the classrooms?

Observations were conducted over five weeks during the middle of the semester. Seven classes, two from receive sites and five from the origination site, were observed. Interviews were conducted on an informal basis before and after each of the five origination site observations with 6 of the 19 origination site students and 6 of the 7 receive site students. In addition structured interviews were conducted, both on an individual and small group level, to cross check perceptions.

The authors reported finding the following results. Although there were problems with the technology, students at the receive sites tended to be tolerant of these problems,

while some students at the origination site tended to be less so. However, the receive students noted that problems of distance were a concern. Problems of this type include getting graded work back in a timely manner, and receiving handouts and articles in time for the class meetings. A major problem existed with the use of the microphones. Several students at the origination site often did not use them, which frustrated the receive site students, since they could not hear the question being asked, or the comment being made. The authors also stated that there was no indication of classroom community between the origination site and the receive sites, or among the receive sites themselves.

The authors concluded the article by making the following suggestions for teachers using technology such as was used in this study. Their suggestions are based upon student comments and reactions to observations. First, there should be other technologies to support lost interactions, such as FAX machines and toll free phone numbers. Also, the instructors should use teaching strategies that make the class seem less impersonal. Simple things, like calling the remote site student by name, rather than the town the receive site was located at, or allowing a few minutes at the beginning of each class for the students at each site to "chat" would help accomplish this. A third suggestion is that the teachers should try to make sure that all materials are ready and available to all students before each class. Fourth, attempt to minimize the problems that naturally occur between traditional and non-traditional students by carefully selecting students for each distance learning course. It was noted that non-traditional students at both the receive sites and in the main site were frustrated with "those young kids."

Finally, before or during the first class session, it is recommended that all of the students be taught the proper use of the technology. The authors conclude the article by listing several future research questions with a distance learning theme.

Yakimovicz and Murphy (1995) presented the results of a study of non-traditional students in a graduate course about distance education at Texas A & M University. The class itself was taught using distance technology, such as audio and video conferencing, computer e-mail, and computer discussion groups. Although several aspects of the distance course were studied, in this article the portion presented explored the experiences of the students with the technology.

Data for the study were collected from four different sources: 1) student journals, in which each student wrote reflections describing their views on using the Internet as a communications tool; 2) taped interviews with each of the 11 graduate students participating in the course; 3) a review of messages on EHRD689, which was the class-wide electronic discussion group; and 4) student evaluations of Globaled-93, which was also an electronic discussion group, but involved students from five other universities. The data was triangulated in order to help ensure the integrity of the findings. The eleven students were located at three different remote sites.

When analyzing the data, the authors noticed that when the course first began, the students experienced problems with the hardware and software, which could be expected. However, since the students shared these adversities, and realized they were all going through similar circumstances, they seemed to work together in order to overcome these problems. The class quickly developed a sense of community. The

authors speculated that this was due partially to the design of the course, which required the students to work together in small groups via the Internet. It could also be that the connections between the students were made quickly as a result of having e-mail and the discussion groups. A change in the motivation of the students was also noted. When the course began, earning a good grade seemed to be the primary motivation in getting the students to collaborate using the technology. As time went on, grades seemed to become less of an incentive, as students learned to feel comfortable exploring with and using the Internet for class projects.

The authors concluded the article by stating that they are unsure whether this technique of distance education would work in other settings. Since they had a relatively small group of all graduate students, they would not speculate if the results would be duplicated on a group of more traditional, undergraduate students.

The five studies just discussed reflect what most studies have discovered about Instructional Television and similar technologies: they often contradict each other, depending upon the circumstances. Hornik (1974) found that the introduction of a new technology into an educational system made an academic difference. Cennamo, Savenye, and Smith (1990) discovered that if a learner perceives a technological medium is difficult to learn from, the achievement of that learner would be lower. Smith and McNelis (1993) discovered that, in general, those students enrolled at a distance found the ITV classes to be informative and helpful, while those located on the campus of the host site (the host class) believed the technology to be a distraction. McHenry and Bozik (1995) found similar results as Smith and McNelis: students at remote sites tended to be

more tolerant of the technology than those at the host site. They also noted problems with those students at the host site working collaboratively and cooperating with those at the remote sites, and that the sense of "community" found in geographically intact classrooms did not exist in this situation. Yakimovicz and Murphy (1995) found just the opposite about community. In their class, the sense of community developed quickly. Of this, they believed it was due to the fact that the students used the Internet. They also found students developing intrinsic motivation for their studies rather than strictly extrinsic motivation (i.e. a grade). They again attributed this fact to the use of the Internet in conjunction with the video and audio teleconferencing.

However, as pointed out by Hiltz (1993), previous studies of courses delivered by television and other non-computer media tend to indicate basically no difference in outcomes. This doesn't mean that under certain conditions and in certain situations, students do not learn more of a certain subject or skill from one medium when compared to another. It simply means that the results of the broad comparisons say that in general there is no significant difference.

### **Distance Education using the Internet**

This section examines some recent studies concerning learning in the virtual classroom, culminating with a look at learning at a distance using Computer Mediated Conferencing.

Hiltz (1993) reports the results of a quasi-experimental study using the Virtual Classroom, the software system designed to support asynchronous group-oriented

learning processes for distance education, especially at the college level. The author wished to answer the following questions:

- 1) Is the Virtual Classroom a viable option for educational delivery (i.e., are the outcomes at least as good as outcomes from face-to-face, traditional classroom courses)?
- 2) What variables are associated with especially good and especially poor outcomes in this new teaching process?

The author notes that the Virtual Classroom project differs from other research concerning computer-mediated communication (CMC) in two ways. The software was designed with the intention of enhancing the normal functions provided by CMC in order to support group-oriented educational processes for the class. Also, a conceptual framework and set of evaluation tools were designed and applied in order to assess the effects of the software.

The Virtual Classroom was used in five different courses offered by three universities involved in the study. The courses were Introduction to Sociology, Introduction to Computer Science, two different statistics courses, and a course on management. Face-to-face and on-line sections of these courses were matched. This was done because students could self-select the environment in which they wished to learn, and the nature of assignments differed between matched sections.

The measured variables were subjective satisfaction with the Virtual Classroom, use of the system by students (in terms of time), and educational outcomes. Results from the study show that the subjective student assessments of the Virtual Classroom were

favorable. The students believed that the course delivery processes did encourage collaborative learning, although there was significant variation in these opinions, depending upon the course. Students in general reported that the Virtual Classroom environment improves the overall quality of the learning experience. The final semester grades between students in the experimental group and those in the control group did not significantly differ, except in one course, Introduction to Computer Science, where the students working on-line had significantly higher final grades.

The researcher also found that students with more positive attitudes towards computers at the outset of the study were more likely to report more favorable outcomes, and spent more time on-line. While positive attitudes towards computers in general were not significantly related to the course grade received in on-line courses, expectations about the mode of learning were significantly related to course grades. The author believes this implies that the choice of enrolling in an on-line course should be that of the student, and those with poor attitudes towards the technology ought not be forced to participate.

The author concluded that the effectiveness of the Virtual Classroom is dependent upon other factors besides hardware and software capabilities, such as the abilities and motivations of students, the teacher conducting the course in an appropriate manner, the nature of the course materials, and the characteristics of the students.

Cheng, Lehman, and Armstrong (1991) describe a study that tested the effectiveness of computer-mediated instruction used in a graduate-level course. They sought to evaluate the impact of CMC on achievement, user perceptions, and attitudes.

Fifty-three students participated in the study. Twenty-five of the students were in the distance learning course, while the other twenty-eight were in a parallel course offered on campus. The course, "Microcomputer Applications in Education and Training" was a three-credit course offered at Purdue University in the spring of 1989. Knowledge of course materials and learner attitudes were assessed at the beginning and end of the semester. Pre-study data suggested that the experimental and control groups were similar in knowledge and background.

Because of difficulties with the hardware and software, the off-campus group was further subdivided into two groups. One group learned from print material and did not send e-mail or participate in computer conferencing. In essence, they were taking the course in a manner similar to correspondence courses. The other group did participate in CMC and learned the course material via the computer network. The on-campus group was taught in the traditional lecture method. The content for all groups was identical.

The results showed a significant difference in achievement between the three groups. The correspondence group was significantly higher, while the CMC group had the lowest scores on the final tests. However, the overall final grades showed no significant differences between groups. The authors cite the nature of the final test, a low-level recall examination test, as one possible explanation for this discrepancy. Also, the fact that the correspondence group was supposed to be a CMC group, then had methods changed, may have led to overcompensation on the part of that group.

As for time on task, the two distance learning groups spent significantly more time on task than the on-campus group, with the correspondence group spending the most time on task.

There were only two significant differences in attitude measurements. The computer conferencing course members believed that the course was not taught at the right level for the materials learned. The other difference was found between the computer conferencing group and the on-campus group: the computer conferencing group believed they worked much harder in the course than their on-campus counterparts. Finally, all groups had higher scores on the attitudes-towards-computers scale at the end of the study.

The authors concluded by stating that the study provided insufficient evidence to suggest that computer conferencing was not an acceptable alternative method for teacher training. However, they could not conclude that their study showed it to be an acceptable alternative. Despite some of the negative findings, the authors believed that the overall results of the study were encouraging.

Schutte (1996) reports the findings of an experimental study done in his Social Statistics courses at California State University at Northridge. Schutte notes one of the reasons for the study was the lack of quantitative studies regarding the effectiveness of the virtual class versus the traditional class with regards to student performance.

The sample in Schutte's study consisted of 33 students in a Social Statistics class, who were in the class for the entire semester. Of those, he placed 17 in the traditional class setting, and 16 in the virtual class. The traditional class students attended class as

usual, listening to lectures, handing in homework assignments, and taking examinations. The other group took an on-line version of the course, completing assignments on a World Wide Web site, posting questions and comments to an electronic discussion list, and meeting with their professor in an Internet chat room. Each section was given identical instructions by the instructor as to the scope, content, and expectations for the class. After an initial orientation session, these students only went to the classroom for the midterm and final exam.

Results from the exams indicated that the students who took the course in the virtual setting scored on average eighteen points higher on the midterm, and twenty points higher on the final. These results held across all four question types in his exams (matching, objective, definitions, and problems), and all were significant differences ( $\alpha = .10$ ). Post-test results found significant differences in the two attitudes of the two groups towards mathematics, the amount of student contact, the time spent on the class, perception of flexibility of the class, and the understanding of the material. A demographics survey found no significant differences in age, sex, ethnicity, college year, or grade point average between the two groups.

Schutte noted that the results surprised him, that he expected the reverse situation: the traditional class students would do better. He believed that part of the reason for the better performance on the part of the students in the virtual class could be found in the fact that they formed study groups to compensate for the lack of face to face meetings with the instructor.

Schulman and Sims (1999) documented the findings of an experimental study conducted during the fall semester of 1997. Students enrolled in five undergraduate on-line courses participated in the study, designed to measure the learning of the course material. The course titles were Organizational Behavior, Personal Finance, Managerial Accounting, Sociological Foundations of Education and Environmental Studies. In total, 40 undergraduate students were enrolled in the on-line courses and 59 students were enrolled in the in-class courses during this period.

A pretest was given to measure the level of knowledge students had of the course content prior to the start of the courses. Once the coursework was complete, a posttest was given to test the course content. Using a matched t-test, the results indicated that for both groups, the posttest was significantly higher than the pretest. On the pretest, the online group scored significantly higher than the in class students did, yet on the posttest, there existed no significant difference between the two groups.

The authors conclude by stating their results may indicate that students who self-select for on-line courses may be better prepared for the course material than those students who choose an in-class version of the course.

Walther, Anderson, and Park (1994) report the findings of a meta-analysis that examined the effects of time restriction on social interaction in CMC. One area of examination concerned the cues-filtered-out perspective. This is a catch all term for several theories that describe antisocial and/or impersonal communication in CMC. There are several studies that support the notion that, due to the lack of non-verbal cues in CMC use, uninhibited confrontational communication (flaming) is common in CMC

courses. The authors of this study state that this is a case of over-reporting. They found little evidence of flaming in CMC, and found CMC groups with no examples at all. They cite other studies that suggest that the lack of non-verbal cues is an insufficient predictor of the nature of CMC interaction.

The social information processing perspective is presented as an alternative to the cues-filtered-out approach. This perspective believes that CMC cannot convey all the task-related and social information in as little time as face to face communication can, but the users of CMC adapt into the stream of language and textual behaviors messages that might otherwise be non-verbal. Therefore, more time may be needed in CMC situations than in face to face communications in order to completely exchange all information.

The meta-analysis examined more than 350 reports on CMC conferencing, asking two questions. The first hypothesis dealt with socially-oriented communication, the second with limitations on message exchanges. In particular, the first hypothesis stated that they believed there would be a greater proportion of socially oriented communication in unrestricted (time-limited) than in restricted (time limited) CMC interaction, and the difference between face to face and CMC interaction on socially oriented communication is greater in restricted than unrestricted interaction. The second hypothesis stated that there would be a smaller proportion of negative/uninhibited communication in unrestricted CMC interaction, and that the differences between CMC and face to face interaction on negative/uninhibited communication is greater in restricted than unrestricted interaction. Because of several factors, only 21 studies were used to analyze hypothesis one, 14 to analyze hypothesis two.

The results showed the first hypothesis to be supported. In other words, there was a greater proportion of socially-oriented communication in unrestricted CMC interaction than restricted, and that the ratio of CMC to face to face on socially-oriented communication is more positive when interaction is unrestricted. Although there were differences supporting hypothesis 2, the differences were not significant; therefore, hypothesis two was rejected. However, the authors conclude by stating that since no differences were found on the negative social dimension, it must be the positive end of social CMC that changes over time; and that this hypothesis in its own right deserves further study.

Gunawardena, Lowe, and Anderson (1997) documented their findings of a study done concerning the social construction of knowledge during an on-line debate using CMC. In particular, they wished to find out if knowledge was constructed within the entire group by means of exchanges among the participants, and if individual participants changed their understanding, or created new constructions as a result of interactions with the group.

The subjects for this study were the participants in an on-line debate that took place June 5-11, 1995 as part of the World Conference of the International Council on Distance Education. Five hundred and fifty four members were invited to choose either the affirmative side or negative side of the question being posed to the debaters. Asynchronous communication in the form of posting to bulletin boards was used as the method of communication among the debaters. Most of the 554 participants were specialists or advanced students in the field of distance education.

To analyze the communication that took place, several methods were considered and then discarded, due to some inherent weakness noted by the authors. Instead, the authors developed their own instrument, the Interaction Analysis Model for Examining Social Construction of Knowledge in Computer Conferencing. This model looked at the content of the message, and scored it in one of five hierarchical "phases":

1) Sharing/Comparing, 2) Dissonance, 3) Negotiation/Co-construction, 4) Testing Tentative Conclusions, and 5) Statement/Application of Newly Constructed Knowledge. According to the researchers, the first two represent lower mental functions, the top three represent higher mental functions, with the top phase representing metacognition.

The results of the weeklong debate showed a majority of postings and a majority of references to resources at Phase II or Phase III. This, according to the authors, indicated a fairly high quality, with several participants involved in exploration of dissonance or inconsistency, and the negotiation of meaning and co-construction of knowledge. The authors also recognize that the debate format hindered the natural development of Phase V communication, since members were instructed to remain on their "side" of the debate throughout the conference. Despite this, all five phases were represented throughout the conference.

The researchers conclude that the interaction analysis model they developed did enable them to appropriately analyze the exchanges among the participants to determine if knowledge construction had taken place. They hope that the model will encourage further study of interaction, and will change the focus of the function of CMC as a

process of knowledge creation, rather than focusing on connected messages with no regard to content.

### **Computer Use in Mathematics Education**

The next several studies examine some of the recent work that has been done concerning use of computers for mathematics education. The first section summarizes findings of several studies done on using the computer as an educational tool in mathematics in a non-distance education setting. The final section focuses in detail on two studies that examine the effects of cooperative group learning when using the computer.

Akbari-Zarin and Gray (1990) documented the findings of an experimental study to determine if the software developed for a college finite mathematics course was effective in enhancing critical thinking skills. They also were interested in discovering the attitudes that the students had towards the software. They found that the software did make a significant difference when compared to the control group, and that the majority (75%) of the students had a favorable reaction to using the software. They attribute this to the design of the software: it focused on more complex problems, rather than repetitive tasks, which tend to get a less favorable reaction among students.

Judson (1990) documents a similar experiment, this time using a calculus class and the program Maple. Her findings showed no significant differences between the control and experimental groups in achievement. When student attitudes were surveyed, the students responded negatively to the use of the software package, citing the use of the software required "too much work" for the minimal (if any) benefit gained.

Funkhouser and Dennis (1992) studied the effects of computer-augmented mathematical instruction on problem solving for high school students. The findings showed that the experimental group did perform better on standardized tests in geometry and algebra, in addition to showing a significant gain in solving word problems. However, all other academic measurements showed no significant difference, so the authors concluded that their results were mixed.

Funkhouser (1993) followed up this study with a report on the student attitude towards mathematics by those who used the software. He reports that students who used the problem-solving computer software were more positive about themselves as learners, and had a more positive view of mathematics as a discipline.

Mayes (1992) conducted a similar experiment to Funkhouser and Dennis, except his control group received training in problem-solving skill, in this situation not using a computer. Results showed that both control and experimental groups made gains, but the experimental group posted gains for students at the medium and high level of mathematics ability, while the control group posted gains at the low and high level of mathematics ability. Mayes concluded that students at lower levels of ability may not be able to overcome the problems of learning the technology.

Tilidetzke (1992) studied the effects of computer-aided instruction (CAI) on college algebra students. His results showed that the experimental and control groups had no significant differences in academic achievement. He concludes by stating that this result shows CAI may be a viable alternative to classroom instruction in a college level algebra course.

Other studies in various mathematical disciplines and over various ages find similar results: the group(s) using computers either outperformed or performed the same as their non-computer counterparts (Heid, 1988; Ayers, Davis, Dubinsky, and Lewin, 1988; Palmiter, 1991; Tall and Thomas, 1991). Most cite one other reason beyond the software or use of the computer as the possible reason for gains. This is the Hawthorne Effect; students respond because the use of computer software or computers for education is new. Other reasons, such as difference in instructors, or pre-existing differences are cited by some of the authors.

One item of interest can be found in the Judson (1990) study. The students did not make any significant gains in achievement in this study, and they also reported having a negative attitude towards the use of software. This seems to correspond with the findings of ITV and other video technologies; that achievement and attitude towards the technology seem to be tied together.

### **Collaborative Learning using the Computer**

Mevarech, Silber, and Fine (1991) documented the findings of an experimental study whose major purpose was to determine the effects of cooperative computer assisted instruction (C-CAI) and individualistic computer assisted instruction (I-CAI) on mathematics achievement, mathematics self concept, and mathematics anxiety. Also of importance was to determine to what extent do the methods exert different effects on low, medium, and high ability students.

The sample was made up of 149 sixth grade students from one school located in a suburb of Tel-Aviv, Israel. Seventy-eight of the participants were boys, seventy-one

participants girls. Subjects had no prior experience with computers, as none had families that owned a home computer nor had the school purchased computers at this point. Subjects were given a pretest to rank them into three different ability groups: low, medium, and high.

To measure achievement, the software itself was used to evaluate each student's the mathematical achievement of each student. Scores were presented as a two-digit number. The first digit represented the grade level of each student, the second digit represented the month. For example, a grade of 62 would indicate that a particular student was performing at the ability level of a sixth grader, at the second month of schooling. These scores were obtained at the beginning of the study, at the end of the study, and two months after the study had ended. In addition, the Arithmetic Achievement Test was administered before the study began, to determine each student's beginning level of mathematical achievement. The scores from this test were used as a covariate.

The affective variables were assessed by a thirty-item questionnaire; 18 of the items were designed to measure mathematics self-concept (MSC), with the other 12 items designed to assess mathematics anxiety (MA). The test was adapted from a questionnaire designed by Mevarech and Rich (1985). This test was given one week before the beginning of the study, and at the end of the study.

Based upon the pretest, the students were separated into groups of three. Out of these triads, students were randomly assigned to work either in pairs ( $N=90$ ) or as individuals ( $N=59$ ). Each week during the study, students would have two 20-minute

sessions at the computer. The students working in pairs (C-CAI) took turns at the keyboard, discussed problems, and together decided upon the correct solution. The I-CAI students worked with the same program, just as individuals. It should be noted that when all tests were given, students worked on them individually. Students were also allowed to use the system on their own time after the lessons had ended.

Since the variables were all intercorrelated, Multiple Analysis of Covariance (MANCOVA) was used to analyze differences between treatment groups, ability groups, and the interaction on achievement, MSC, and MA. This was followed by several univariate ANCOVA's to determine the effects on each dependent variable. The findings indicate that when overall controlling for initial differences in achievement, the main effects for both treatment and ability were statistically significant ( $p < .05$ ). However, the interaction term was not significant. So, the students in the C-CAI group performed significantly better than did the students in the I-CAI setting.

For mathematics anxiety, again controlling for initial differences in achievement, the interaction term was significant, as was the ability main effect; but the treatment main effect did not find a significant difference for mathematics anxiety. It was shown that although the math anxiety decreased in both groups, the decrease was greater in the C-CAI group than in the I-CAI group. And, the only significant effect on math self-concept was found for ability, meaning the treatment did not make for any significant difference. The authors state that two factors may contribute to this. First, since both the pretest and posttest mean scores on MSC were near the maximum possible score, the ceiling effects may have confounded the treatment effects. Secondly, since it was the

first time that all students were exposed to the use of a computer, the use may have affected them equally.

The authors concluded that the main reason for the advantages gained by students in the C-CAI groups was the interaction between students during the learning process. They state that future research should examine student's learning interaction when using computer program other than the drill and practice kind used in this experiment; for example, a program that focuses on problem-solving tasks.

Hooper (1992) documented a study that compared the effects of completing computer based instruction in groups and as an individual, investigated the effects of group composition (heterogeneous or homogeneous) on achievement, and identified relationships between intragroup discourse and achievement.

The sample for this study consisted of 115 fifth and sixth grade students from a suburban, mostly white middle school. The students were classified as high ability or average ability in mathematics based upon the mathematics subscale of the California Achievement Test (CAT). The mean percentile CAT score for the high ability students was the 95<sup>th</sup> percentile; for the average ability student, the 64<sup>th</sup> percentile. After randomly assigning the students, a total of 36 students worked individually, with 20 being classified as high ability, 16 classified as average ability; the rest (79 students) worked in groups of 2 (usually), with 38 of those students classified as high ability, 49 as average ability.

Before the study began, the students participated in a 90-minute training session on learning how to work in groups, and how to communicate effectively within a group.

Observers were also trained on how to recognize and record various interactions between students.

The tutorial used in the study consisted of three segments. In each, students were instructed, answered practice questions, and then completed a mastery quiz. If they passed the quiz, they went to the next segment. If not, the tutorial instructed the students to find (and if working in groups, to discuss) their errors, then attempt a parallel version of the quiz. After three attempts, if the students still had not mastered the content, they would begin the next segment.

The posttest consisted of 40 questions, with students having a total of 17.5 minutes to complete the exam. The questions were broken into the following four categories: factual (7 questions), application (13 questions), generalization (10 questions), and problem solving (10 questions). The students took the posttest as individuals, with the test being given one week after instruction.

The study reported the following significant differences in achievement. For group versus individual learners, it was found that there existed no significant difference between the two groups on the pretest. On the posttest, it was determined that students who completed the tutorial in groups scored significantly higher than did those students who worked on the tutorial as individuals. For the intergroups, the heterogeneously grouped students scored significantly higher on the pretest than did the homogeneously grouped students. However, on the posttest, the only significant difference that could be found appeared between the homogeneously grouped high ability students and the homogeneously grouped average ability students; and that difference only was significant

in the problem solving part of the posttest. Also, overall the heterogeneously grouped students significantly outperformed the homogeneously grouped students on problem-solving questions, seeming to suggest that heterogeneous grouping may be better for complex tasks.

On the mastery quizzes, another significant difference was found. Students working alone attempted more mastery quizzes than did the students working in groups. Also, as the lessons became more complex, the number of quizzes attempted rose significantly for all groups.

For the amount of time on task, the only significant difference appeared between the homogeneous high ability groups and the homogeneous average ability groups, a result that could be expected.

Concerning the discourse within the groups, some, but not many, significant indicators were found. Helping behavior and the helping behavior of partners proved to be the only significant predictors of posttest achievement. Follow up analysis indicated that high ability students generated significantly more help in homogeneous groups than in heterogeneous groups, with no significant difference found among average students.

The author concludes that both high and average ability students were more successful in completing the tasks in groups than as individuals. This implies that when designing a program for use on the computer, designers should try to make the system as group-use friendly as possible. He further states that these results may not transfer across age groups or subject matter. Also, without the interaction training that the students

received, they may not have attained the same results. Further research is suggested in these areas, as well as conducting a study including low ability students.

These two studies had similar conclusions: students who work in groups with technology, even if they have had no prior experience to computer or software use, make greater academic gains than those who work as individuals. Mevarech, Silber, and Fine (1991) believed that the interaction between the students was the key to the advances gained by the students in cooperative learning groups. Hooper believed that grouping heterogeneously, as opposed to homogeneously, would be better for complex tasks and assignments. The Mevarech, et. al. (1991) study also seemed to indicate that students who worked in groups experienced less mathematics anxiety than did those who worked alone.

### **Computer Anxiety, Attitudes and Gender**

This next section examines some of the literature concerning computer anxiety, as it relates to both age of the student, and the gender of the individual.

Gressard and Loyd (1987) documented the findings of a study designed to investigate the effects of math anxiety and gender on three computer attitudes which have all been identified as being related to achievement in computer related courses: computer anxiety, computer confidence, and computer liking.

Three separate groups, totaling 356 students, were involved in the study. The first group consisted of 161 junior high and high school students who were enrolled in an accelerated language arts class. From this group, 52 of the students were male, 109 female. The second sample consisted of 76 students (37 male and 39 female) from a

small liberal arts college. The third sample was made up of 119 students (50 male and 69 female) who were enrolled in a developmental mathematics course at a local community college.

Computer attitudes were measured by the Computer Attitude Scale, a forty-item questionnaire developed by Loyd and Gressard first in 1984, and later modified. The instruments' items can be placed into four categories: Computer Anxiety, Computer Confidence, Computer Usefulness, and Computer Liking. Each category consists of ten separate items, and presents both positively and negatively worded statements. Students respond to each item by selecting one of four possible answers, ranging from strongly agree to strongly disagree.

Mathematics anxiety was measured by using a modified version of the Mathematics Anxiety Scale, developed by Fennema and Sherman in 1976. This ten-item questionnaire also has a set of six responses ranging from strongly agree to strongly disagree. Information about the gender and computer experience of each student was also collected.

The overall means and standard deviations of the Computer Attitude Subscales and the Math Anxiety Scale indicate that the students as a whole had a neutral to positive attitude towards both computers and mathematics. Also, after performing regression analysis for each of the three groups (the junior and senior high students, the liberal arts students, and the community college students), computer experience was found to account for a small but significant amount of the variance of the three computer attitudes (computer liking, computer anxiety, and computer confidence). The correlation between

computer experience and attitude was positive, inferring that more computer experience corresponded to a more positive attitude about computers. For each of the three groups, the addition of mathematics anxiety significantly increased the amount of variance explained in all three computer attitudes. The results suggested that the less math anxiety a student had, the more positive was their attitude towards computers. Finally, for each of the three groups, the addition of the gender variable into the regression equation did not significantly increase the explained variance of any of the three computer attitudes. There was very little correlation found between gender and attitude towards the computer, not enough to be considered statistically significant. The study also found there to be no statistically significant correlation between gender and math anxiety, which seems to contradict several earlier studies. The authors suggest that one possible explanation for the change is that more educators are aware of the anxieties that females have felt towards math and computers, and have taken steps to alleviate those anxieties before they become a block towards achievement.

The authors conclude by stating that mathematics anxiety may be a small but fairly important factor in the high computer anxiety and low computer confidence felt by several junior high, senior high, and college students. The authors suggest that perhaps schools make the effort to disassociate computers and mathematics as being similar subjects. Also, since the study shows that the two anxieties are correlated, perhaps techniques used to alleviate mathematics anxiety can be applied, with some modification, to relieving computer anxiety as well.

Swadener and Hannafin (1987) documented the findings of a survey used to determine attitudes towards computers by sixth grade boys and girls. Since several studies had been done on older students showing differences in attitudes existed between genders, the authors wished to see if the same held true for younger students.

The students in the sample were 32 randomly selected sixth grade students from two schools in a moderately sized middle class suburban/rural school district. There were 15 females and 17 males that took the survey.

The instrument designed for this study was a 17-item questionnaire. The items were broken down and classified into four major categories: self confidence in the use of computers, perceived utility of computers, general attitude towards computers, and gender roles in computers. Originally consisting of 30 items, the test was administered several times to a different group of students in order to discard items that were not consistent with the construct assessed by the individual scales. In the end, four items fell into the first category, self confidence in the use of computers. There were five items each in the second (perceived utility of computers) and third (general attitude toward computers) categories. Finally, there were only three items in the final category, sex roles in computers.

For testing purposes, the students were divided into two different groups, one based upon the gender of the student, the other based upon mathematical achievement. Mathematical achievement was based upon a district-wide criterion referenced mathematics skills test. The survey was done towards the end of the school year. It

should be noted that there was never any formal instruction in the use of computers for any of the students prior to this study.

Results in each of the four categories were computed (using ANOVA) and reported. Under the self-confidence in the use of computers category, a significant difference was found based upon mathematical achievement. The higher achieving students had significantly more self-confidence than the lower achieving ones. There was no significant difference between genders in this category.

For the perceived utility of computers category, a marginal interaction was found. The low achieving females rated the utility of computers higher than the high achieving females. For the boys the opposite was true: The high achieving boys rated the utility of computers higher than the low achieving boys. However, no main effects were found for either gender of student or mathematics achievement.

Under general attitude towards computers, the same results as for the second category occurred. No main effects were found, and a mild interaction was obtained. Again, the high achieving females sided with the low achieving males in reporting a less positive attitude, and the low achieving females joined the high achieving males in reporting a more positive attitude towards computers.

The three questions that dealt with sex roles in computers were evaluated individually, rather than as a group. Interestingly, in all cases the ratings by male and female sixth graders were virtually identical, both for their own gender as well as towards the opposite sex. This is in direct contrast to similar studies done with high school students.

The authors raise several points of discussion based upon the results. First and foremost, these findings suggest that boys and girls at this level respond with greater similarity than difference. Also, it appears that self-confidence is an important factor in computer participation for both sexes. And, although the fact that the high ability females and low ability males responded the same on two of the categories is perplexing, the fact that the sample size was small may have accounted for this oddity.

The authors conclude the article by stating it appears that changes in attitudes among the sexes towards the use of technology occur somewhere between the sixth grade and the upper grades of high school. Attempts to understand more precisely the influences that effect perceptions towards computers in junior high and high school may yield methods to keep females interested in working with computers.

Hayek and Stephens (1989) documented the findings of a study used to determine factors affecting computer anxiety among high school computer science students. The researchers point out that several previous studies (including Gressard and Loyd, 1987) found no, or very small, differences in anxiety levels for males and females. They summarize that the research is similar to that done on mathematics anxiety; that differences, if found, are usually small and almost always favor males.

Computer anxiety in this study was measured by the Computer Anxiety Index (CAIN). The CAIN uses a Likert-type inventory scale; the higher the score, the more computer anxious the individual is determined to be. Computer science aptitude was also measured. The instrument used to gather this information was the Konvalina-Stephens-Wileman (KSW) Computer Science Aptitude Test. Both instruments have been shown to

be valid and reliable in various studies (Maurer and Simonson, 1984; Wileman, Konalina, and Stephens, 1981). Mathematical Competency was also checked, using the Beckman-Beal Mathematical Competencies Test for Enlightened Citizens.

Fifty-two students in grades 10-12 enrolled in computer science courses participated in the study. There were nine sophomores, eleven juniors, and thirty-two seniors enrolled; nineteen of the students were female, while the remaining thirty-three were males. Most (42) of the students were enrolled in a beginning computer course (BASIC Programming); only 10 were enrolled in the advanced course (Advanced BASIC). It should be noted that of the 10 enrolled in the advanced course, only one was female.

During the first week of the semester, the CAIN, KSW, Beckman-Beal and demographic surveys were administered. At the end of the semester, the CAIN was readministered to obtain a post-course anxiety level.

A t-test was used to compute the results. The results showed that students who had prior experience with computer use, and those who had a computer at home had significantly lower levels of computer anxiety ( $p < .01$ ). The use of a computer on the job by a parent, college degree of parent(s), sex of the student, and completion of the first semester of BASIC had no significant effect on the level of computer anxiety in this study. The study also showed that both pre-course and post-course anxiety scores were related to the final course grade that the students received.

The conclusions made by the authors were brief. They believed further research ought to be done concerning the effects of the specific type of computer exposure that

might best reduce computer anxiety. They also believed that research might be done to determine the optimal time to introduce computers into the classroom experience, given that they are a necessity in almost every aspect of society today.

Dyck and Smither (1994) studied computer anxiety among adults, rather than focusing on the typical school-aged individual. They wished to compare the computer anxiety levels between a group of college students and senior citizens living in the same geographical area.

Two hundred and nineteen college and university students participated in this study, along with two hundred and three senior citizens. Among the college students, 77 were male, 142 were female, with an average age slightly less than 22 years of age. The average age of the seniors was roughly 67; there were 71 males and 132 females among the older subjects.

The Computer Attitude Scale, developed by Loyd and Gressard in 1984 was one of the instruments used in the study. The Computer Anxiety Scale was also used, since the researchers believed it to be representative of more specific situations, while the Computer Attitude Scale was more general. Questionnaires asking about demographics and computer experience were also issued. Subjects first answered the questions on the demographics survey and the computer experience questionnaire. Then the subjects completed the Computer Anxiety Scale and the Computer Attitude Scale.

Results showed a relationship between computer anxiety and computer experience in both age groups. This held true regardless of sex; however the relationship

between computer liking and computer experience was found to be lower for females than for males.

A MANCOVA was analyzed using as independent variables age and gender, covariate computer experience, and dependent measures scores on the Computer Anxiety Scale and Computer Attitude Scale, and number of years of education. The results, when examined for age affects, found differences on all scales. Older subjects had less computer anxiety, had a more positive attitude towards computers, and indicated more liking for computers than the younger subjects. However, older subjects also indicated less computer confidence than did younger subjects. When the results were examined for gender affects, the only difference was found to be in the number of years of education, with the males having more years than females. There were no differences among the genders in any of the computer attitude or anxiety scales.

The researchers concluded both age groups showed a correspondence between lack of computer experience and higher levels of anxiety. There existed no significant differences in anxiety between sexes. The authors believe that the reason differences exist on the attitude and anxiety scales warrants further investigation. They hypothesized it could be due to how each group has predominantly used the computer in their lifetimes.

## CHAPTER 2

### DESIGN OF THE STUDY

#### Conceptual Framework

As described in the Literature Review section of Chapter 1, the use of distance learning is a viable alternative to traditional classroom teaching. In most of the studies, the students could easily communicate using CMC with other members of the course, but it was rare that students worked together in collaborative, long-distance groups (Hiltz, 1993; McComb, 1993). For those that did, asynchronous communication was always the method of choice for communication; synchronous communication was not used.

As the use of distance courses offered over the Internet increase, so too will the questions pertaining to the most effective way to conduct such courses. One of the major questions in this regard is the effectiveness of the communication between students or between the student and the professor. In his study, Shutte (1996) hypothesized the reason students taking the course over the web outperformed those in his classroom was due to the fact that students in the experimental group were "getting together and working on the assignments". Other researchers came to the same conclusion about group work among students (Mevarech, Silber, and Fine, 1991). Of course, this is virtually impossible for students learning in a true on-line distance education format. Instead, if these students, are to "get together and work in groups," they will have to do so in a virtual format using a method of communication made available to them. This probably means one or both of the following formats: bulletin board or chat rooms. But does the

communication on line (i.e., the amount of communication, and/or the intellectual level of the communication) affect academic performance? And does students communicate differently on-line depending upon location, that is, depending on whether they are on campus or off campus? That was what this study intended to find out.

Gunawardena, Lowe, and Anderson (1997) studied the use of computer-mediated conferencing for a global online debate in an attempt to examine the negotiation of meaning and the construction of knowledge that took place in that collaborative learning environment. Their results from this and another study confirmed their belief that the instrument they used was valid - that it accurately reflected the knowledge construction of the participants in computer-mediated conferencing. However, in both uses of the instrument, the audience consisted of primarily professionals, all approximately equal in skill and knowledge. They recommend that the instrument be used for the evaluation of computer-mediated conferences where there exists a moderator or teacher of greater skill, so long as this moderator is open to conceptualizing the learning process as joint construction of knowledge. Such was the case in this study. This study will add to the body of knowledge of how computer-mediated conferencing allows for the construction of knowledge on the part of the participants. This will hopefully lead to better design of distance learning courses that contain computer-mediated conferencing or collaborative group work as a primary component of the course.

### Description of the Population

The population of this study consisted of students who were enrolled in two courses offered by the Department of Mathematical Sciences at Montana State University during the Spring Semester of 1999 and that used web based instructional and communication materials as a primary feature of the course. The students who enrolled in these courses during this semester comprised a fairly homogeneous group; most were pre-service or in-service middle school and/or high school mathematics and science teachers. A large percentage of the in-service teachers who enroll in distance education courses are working towards completion of a master's degree in mathematics education or a master's degree in science education. Each semester one to three courses fitting this description are offered in the department of Mathematical Sciences, and enrollment is typically between 15 to 20 students in each class. Enrollment in these classes is slightly higher in the summer. All members of the population were included in the study.

The population for this study consisted of 18 students enrolled in Modern Geometry offered at Montana State University in the Spring Semester of 1999. The course was offered as both an undergraduate course (Math 329) for pre-service secondary mathematics teachers and a graduate course (Math 527) for in-service secondary mathematics teachers. Fourteen of the eighteen students were enrolled in the Math 329 level of the course, four in the Math 527 level of the course. Even though one course was an undergraduate level course, the other a graduate level course, the content of the two courses was identical. A course syllabus can be found in Appendix C. The course was not taught in a traditional lecture setting; instead, the course materials (with the exception

of textbooks) were delivered to students via the Internet through the use of the World Wide Web. The students who enrolled in this course were mostly secondary mathematics teachers or undergraduate students majoring in secondary mathematics education, although enrollment in the course was open to any student who met the prerequisites.

All four of the students enrolled in the graduate level version of the course (Math 527), and one student enrolled in the undergraduate level version of the course (Math 329) resided off campus during the duration of this study. The other thirteen students enrolled in the undergraduate level version of the course (Math 329) were all undergraduate students who were taking other courses on campus at Montana State University during the spring semester of 1999.

The eighteen students were placed into four collaborative work groups consisting of four or five students each. The five distance students made up one group. The other three groups were made from the thirteen on-campus students. The members of these three groups were chosen by matching on prior mathematical ability, with gender as a secondary matching variable. Prior mathematical ability was determined by the student's college grade point average in all mathematics courses that count towards earning a degree in secondary mathematics. Students did not "self assign" themselves into any group. Once a member was placed into a group, he or she was not moved to another group.

In addition to completing the group problem-solving tasks on-line, the on-campus students had the opportunity to meet during the week to discuss these tasks as well as other concerns associated with the course. The students who took the course at a distance

also had these same opportunities, but each meeting was conducted completely on-line using the MSUlink First Class Client synchronous chat room.

Conducting the study in the Modern Geometry and Geometry for Teachers courses as opposed to the other courses offered with a distance learning component was primarily the choice of the researcher. While there existed about 10 other distance education courses offered during the 1999 spring semester at Montana State University, Geometry for Teachers and Modern Geometry are mathematics courses, which is the major field of study of the researcher. The students who comprised this class were a fairly homogenous group; most are or soon will be secondary mathematics teachers.

The reason that matched samples were used to create the heterogeneous undergraduate groups was to help eliminate extraneous variables, and thus help diminish the variability among those groups caused by factors other than the treatment. It was also theorized by Hooper (1992) that heterogeneous groups did better on complex problem-solving tasks than did homogenous groups.

### **Description of Treatments**

The treatment in this study was the use of on-line communication tools in order for the students to communicate in their problem-solving groups when solving each weekly task. This communication could take place either as a message posted on the bulletin board (asynchronous communication), or through the use of the chat room (synchronous communication). Messages and chats were posted in each group's "folder". The folders were labeled according to group name - Red, Blue, Green, or Yellow. As

described earlier, each group consisted of four or five students from the Modern Geometry or Geometry for Teachers courses. The undergraduate students were heterogeneously matched into each group according to their prior mathematical ability; the off campus students comprised one group. The mathematical content covered by all groups was identical. The study analyzed the manner in which the students communicated with each other when solving the group tasks.

The Modern Geometry and Geometry for Teachers courses for spring semester 1999 were 15-week courses. During the first two weeks, students were given activities to familiarize themselves with MSUlink and the First Class Client software, the software they used to communicate with each other and the instructor throughout the entire course. After this, for eleven weeks, the students were required to complete one activity per week on-line working in their assigned groups. Each week all four groups worked on the same problem. For the last two weeks of class no group activities were assigned; instead the students completed other work, such as their final project, and took the final test. For a complete syllabus of the course, see Appendix C.

The weekly group tasks were to be addressed collaboratively, with each student contributing ideas, responding to ideas, proposing strategies and procedures, demonstrating solutions, and summarizing and reporting their groups' findings. A complete record of each groups' deliberations was recorded in electronic form using First Class Client's messaging and chat tools. Substantive contributions to these deliberations that took place in face-to-face or phone conversations were to be referenced and

reiterated in the on-line electronic communications of the group. Groups failing to do so were to score lower on weekly group tasks.

When students were working on the assigned group task on-line, they could use either the synchronous communication environment or the asynchronous communication environment. Students could use other methods of communication, such as e-mail, face to face discussions, and even phone conversations to discuss the problem with other group members, or with other members of the class. Students could have even queried students from the other groups; this can be done on-line, through phone conversations, etc. However, any pertinent and relevant information related to solving the task was to be recorded on-line in their group folder. This was done automatically if the information was in the form of a bulletin board message; if it was in the form of a chat, a student would have to post that message on the system. For bulletin board postings, it was not a requirement that students make a set amount of posting per week, although they were highly encouraged to use the software as much as possible. It was also not a requirement that each member of the group be present at all times for all chat room meetings, but regular attendance was expected. Once the group has solved the problem to their satisfaction, they would e-mail their answer to the instructor. The group was to decide who would complete this task; the instructor did not designate a group member.

The group problem-solving task was usually posted Monday morning and students had until Sunday evening at 5:00 Mountain Time to complete it. Assessment of the activities was based on the same criteria for each group, not depending upon which of the two communication environments were used to complete the activity, or how often

the communication environments were used. All members of each group received the same grade on each task. For a complete listing of all group tasks, turn to Appendix B.

For the thirteen on-campus students, the weekly classroom sessions were as follows. On Monday from 10:00 to 10:50, the students met in the mathematics building for a group discussion and recitation meeting. In this meeting, the professor briefly discussed the recently completed group problem-solving activity, explaining the solution(s) and describing the different possible ways to arrive at the solution(s). The session was also used to allow students the opportunity to ask questions pertaining to that problem-solving activity, any previous activity, or any other homework that has been assigned by the instructor.

On Tuesday, from 10:00 to 10:50, the students met in the computer laboratory for a demonstration/question and answer session pertaining to the technical aspects of the course. In this session, students were given the opportunity to practice working with the software required for the course, and were allowed to ask questions they might have had concerning the proper uses of the software. The Monday and Tuesday sessions were attended by both the instructor of the course and this researcher, whenever possible.

On Thursday or Friday, each of the three on-campus groups met with the instructor and researcher for 20 to 30 minutes. This session was dedicated solely to the discussion of the weekly group problem-solving activity. In these sessions, students asked questions they might have had pertaining to the assigned activity.

The group of on-line distance students had comparable opportunities as those students who were on campus. Although the actual meeting times varied from week to

week, most of the time the following schedule was kept. On Sunday at 4:00 p.m. for one hour, these students met on-line with the instructor to have the group discussion and recitation session. On Tuesday or Wednesday at 4:00 p.m., these students met as a group on-line to discuss any technical problems or difficulties they may have encountered with the use of the software. And on Thursday or Friday, for 20 to 30 minutes, they got together as a group on-line to discuss the group problem-solving activity. All of the students in both environments - that of being on-campus and that of being at a distance - were aware of the format of the class before the course began.

### **Methods of Data Collection**

#### **Academic Achievement**

Group achievement was measured using two different variables. The first was simply the score earned by each group on each weekly task. On most tasks, groups received scores ranging from 80 - 100 on a 100-point scale. For the group work activity each member of a group was given the same score, unless the instructor believed that an individual did not make any contributions in their group to the solving of that task.

During the course of the semester, the ranking of the group tasks according to specific criteria was proposed as an alternative method of ranking the group tasks. This variable was not part of the original proposal for this study. However, it became apparent during the semester that the scores earned on tasks by each group might not be the best predictor of group academic achievement. This was because there was little variation in the scores on the tasks for each group (see Appendix F). Therefore, it was decided to

design a rubric that would discriminate between variations in both content and formatting on the group tasks. This rubric was used to identify variation in the group task that was not readily apparent by looking at the grades. The criteria were developed both the researcher and the instructor of the class. The criteria, with an explanation of its use, can be found in Appendix D. In brief, each task was ranked on its content in two to five distinct areas, on how well the task used or implemented technology, and whether the proper format was followed by the group in solving the task and writing a solution. These three scores (content area, use of technology, proper format) were then summed, and each group task was given a final ranking based on this sum. Ties in the scores were broken by overall content ranking. Scores given by the instructor on the group tasks and ranking of the group tasks can be found in Appendix F, and an example of a solution from each group for a problem-solving task can be found in Appendix E.

The group task found in Appendix E (group task #5) was rated on four content criteria. The first criterion was the proof of the Pythagorean theorem using the approach suggested in `behold.gsp`, a file that demonstrated two solutions of the Pythagorean theorem. The students were to construct the proof according to the means suggested in the file. The group rated best in this category was the Yellow Group, who went above and beyond the requirements of the assignment. They were followed by the Green Group, the Red Group, and the Blue Group, respectively. Therefore, for this content criterion, the Yellow Group received a 1, the Green Group received a 2, the Red Group received a 3, and the Blue Group received a 4. By viewing the proof by each group (in Appendix E), the differences in approach and correctness can easily be seen.

The second criterion asked each group to compare and contrast the mathematics of the two proofs, these being the proofs by Euclid and by Bhaskara. The Red Group (a score of 4) and the Blue Group (a score of 3) barely scratch the surface of the mathematics involved, and thus received lower ratings. The Yellow Group has a much more detailed answer, but the Green Group not only answers the question, but provides an opinion on which they prefer and why. Thus, in this category, the Green Group received the highest rating, or a score of 1.

The third criterion asked each group to compare and contrast the technology used in the two proofs. There was little variation in the answers supplied. The Red Group's answer was fairly terse and not very detailed; thus they received the lowest rating (a score of 4). The Blue Group and the Yellow Group had fairly similar answers. It was judged that the Blue Group's answer was slightly better; thus they received the score of 2, with the Yellow Group receiving a score of 3. The Green Group did a nice job in their analysis, and thus received the highest rating.

The final content criterion dealt with the completeness and accuracy of the essay, which was to answer the question "How may the Geometers Sketchpad and other technologies be used to facilitate the discovery and formalization of proof?" The rating of this category proved to be more difficult than the others, but discrepancies were found. It was judged the Yellow Group supplied the most complete answer, followed by the Green Group, the Blue Group, and the Red Group.

After the rankings of all content criterion, the content scores were summed. The totals found the Green Group with 6 points, the Yellow Group with 7 points, the Blue

Group with 13 points, and the Red Group with 14 points. Thus in the category of Content, the Green Group received a final ranking of 1, the Yellow Group received a final ranking of 2, the Blue Group received a final ranking of 3, with a final ranking of 4 scored by the Red Group.

The technology component of the ratings rubric determined the level of technology in the problem-solving task. The lowest level, entitled "other" was used if the technology use was not appropriate and/or not correct for the assignment. The next lowest, "correct", was used if the group used technology in a correct manner, but still could have made better use of technology in their assignment. The second highest category was "appropriate". This category was chosen if the group used the technology correctly, the format of the technology was appropriate, and the use was of technology was prudent when answering their questions. The highest category "insightful" was used if it was judged a group provided technology above and beyond what was required, and the use of the technology was correct and appropriate.

In this task, it was judged that the Yellow group rated an "insightful" rating for their use of technology, and thus were given a rating of 1 in this category. They provided several examples when solving the proofs. The Red Group and Blue Group rated an "appropriate" use of technology. To break this tie, further detailed analysis was conducted concerning how each group used technology when working on this task. The Blue Group rated a 2 in this category, with a score of 3 going to the Red Group. The Green Group rated a "correct" rating for their use of technology. It was felt that, in comparison with the other groups that this group could have provided more, at least

including in their report one or two images. Therefore, this group received a score of 4 for their use of technology.

Finally, it was judged that all groups followed the format properly. After totaling all scores, the Yellow Group had the lowest score, a total of three. Therefore, their task received the highest rating. The Green Group and the Blue Group had an identical total (five); however, since the Green Group scored better overall in the content criteria, they followed the Yellow Group, with the Blue Group receiving the third best rated group task. The Red Group received the lowest ranking for this group task. The rankings of all group tasks can be found in a table in Appendix F. Note that in that table, the rankings were reversed (i.e., the higher the rank, the better) to allow for direct statistical comparisons.

It was impractical to differentiate achievement levels among individual class members unless using other achievement variables besides that earned during group activities. Therefore, individual achievement was measured by each person's average test score and final test score. The tests given in this course consisted of two parts: a take-home portion, and an in-class portion. Students had one week to complete the take-home portion. It consisted of three to six questions. The instructor designed the questions on this test believing that it would take the students one or two hours to complete each question. These questions usually involved working with the various software packages used in the course, some complicated proofs, or research and discovery questions. In addition to answering each question, the students were sometimes required to write a narrative description of the process he or she used in arriving at their solution. Students

were asked to work on these tests individually; since there was no realistic way in which the instructor could guarantee this, students were on the honor system.

Students were given one hour to complete the in-class portions of the tests. These tests were strictly individual activities, testing on the ideas and concepts presented throughout the course. The instructor or researcher proctored each test. Alignment of all tests to the course objectives was verified by both the instructor and the researcher. Content validity was established by the instructor and the researcher.

### **Communication Phase Level**

Communication phase level was measured using the Interaction Analysis Model (IAM) for examining social construction of knowledge, developed by Gunawardena, Lowe, and Anderson (1997). The IAM was designed to measure the social construction of knowledge in computer conferencing. The designers of this instrument defined five distinct phases of knowledge construction. They are (in hierarchical order) 1) sharing/comparing of information, 2) the discovery and exploration of dissonance or inconsistency among statements, concepts or ideas; 3) negotiation of meaning/co-construction of knowledge; 4) testing and modification of proposed synthesis or co-construction; and 5) agreement statements/application of newly constructed meaning. A copy of the instrument can be found in Appendix A.

The authors used the IAM to rate one entire message, rather than rate different sections of the message as belonging to different levels, as was done earlier by Henri (1992). According to the creators of the IAM instrument, if a message was broken down into units of meaning and each unit analyzed separately, the process by which arguments,

hypotheses, and theories were advanced would be difficult if not impossible to describe. This researcher used the IAM in a manner similar to the creators of the instrument; each complete message received one rating. The authors note that through use in different formats, the instrument has proven valid (Gunawardena, Lowe, and Anderson, 1997).

Phase I and Phase II messages are considered to represent the lower mental functions, while phases III, IV, and V, represent higher mental functions. Phase I, Sharing/Comparing of Information, involves participants putting forth ideas and examples to the group for the purpose of either building consensus through agreement or for alteration by other members of the group if the message does not fit the proposed category. Also in this category are statements of observation or opinion, or the describing or identification of a problem to be solved. Examples of Phase I communication are:

I've been playing around with the sketchpad and have come up with two triangles to work with. I placed one of the triangles so that its vertex is on the coordinate (0,0). The other is an equilateral triangle with the base on the x-axis (Phase I/A - A statement of observation or opinion).

I guess my question is: Is negative space only the different colored space on the inside of the triangle? (Phase I/E - Definitions, description, or identification of a problem.)

The first example exemplifies a typical Phase I message - a statement put forth by a group member for comments by other group members concerning the correctness or incorrectness of the opinion. The second statement illustrates a group member identifying a problem that he or she is having, in this case with the technology used to solve the problem.

Phase II messages represent the discovery and exploration of dissonance or inconsistencies among ideas, concepts, or statements. An example:

...I still have no idea what we are assigned to do. I have gone through a majority of the web pages that our instructor gave us and I still don't see how it helps. Does anyone have a plan of attack? (Phase II/B - asking and answering questions to clarify the source and extent of disagreement)

This message illustrates a step above a Phase I question. In this message, the student has clearly been attempting to solve the problem on his own by reviewing recommended resources. This has created the dissonance in his or her mind, leading to the question being posed to the group as a whole in an attempt to help quell the dissonance.

Phase III messages represent the new construction of knowledge or the negotiation of meaning. This example illustrates a group member helping to solve the dissonance of another in regards to a definition. It is ranked at Phase III not because of the giving of the definition, but because of the explanation that follows. This shows that the author of this message has constructed the proper knowledge concerning invariance under a transformation, and the message allows for the construction of the same knowledge on the part of the readers.

If a line is invariant under a transformation, it is mapped onto itself. For example, in the case of a translation, any line parallel to the slide arrow is mapped onto itself in a sliding motion. In such a case, all points on the line move, but the line is the same. In a reflection, every point on the reflecting line is mapped onto itself. That line is pointwise invariant (Ph III/A - Negotiation or clarification of the meaning of terms).

Phase IV messages involve testing and modification of proposed synthesis or co-construction. In the field of Geometry, like most mathematics, this phase can be most

clearly seen when one group member takes the proposed solution of a problem and tests it against his or her own knowledge. The following message was rated a Phase IV/B, although it could conceivably fall into almost any of the Phase IV subcategories.

I just had time to go through your analytic approach...I am sure you could see the results faster than I did. I agree with all of your calculations except for the radius of the circle. I calculated and found the radius square was equal to  $(10/16)$  and not the square of  $(5/8)$ . I agree with everything else in your report (Phase IV/B - testing against cognitive schema).

Phase V messages require a synthesis or application of the new knowledge gained as a result of working on the problem-solving tasks. The following illustrates an example of one student applying his or her new knowledge to an example designed using a graphics calculator. The message had several attachments, which are omitted here.

...Star 1 represents the pre-image, Star 2 represents the image of Star 1 after the translation  $(-3,-2)$ , Star 3 represents the image after Star 2 has been rotated 90 degrees, and Star 4 represents the image after Star 3 has been translated  $(3,2)$  (see the attachments). In order to view the graphics, you need to have plotpt on the calculator, and then... (Ph V/B - Applications of new knowledge).

Before the actual use of the instrument in this study, the researcher tested the instrument to see if it would accurately measure meaningful communications and constructions of knowledge in a geometry class for teachers. The previous geometry course with an on-line component was offered in the summer of 1998. The structure of the on-line component in this class varied somewhat from the structure in the class under study. Students in the summer course discussed homework problems and problems with the technology within their groups, and among the class as a whole, rather than being assigned specific tasks to be completed through the use of CMC on-line interactions.

However, it was determined that there existed enough similarity that the test would yield meaningful results.

To conduct this pilot study, it was decided that only those messages relating to the mathematical content of the course would be scored; those relating strictly to technology would not, since this study did not look at those messages. That left a total of 215 messages to be scored. The breakdown of the scored messages is as follows:

|                                                 |                    |
|-------------------------------------------------|--------------------|
| Phase I (Sharing/Comparing):                    | 145 messages (67%) |
| Phase II (Discovery/Exploration of Dissonance): | 46 messages (21%)  |
| Phase III (Negotiation/Co-construction):        | 17 messages (8%)   |
| Phase IV (Testing of Co-construction):          | 4 messages (2%)    |
| Phase V (Agreement Statements/Application):     | 3 messages (2%)    |

There were two possible reasons for the majority of the messages being grouped in the lower mental function phases of Phase I and Phase II. One was that the students were not required to complete their assignments on-line: this bulletin board communication was used to discuss difficulties that arose in the homework, which would almost exclusively be categorized as Phase I messages. The second reason had to do with the structure of the homework assignments themselves: most of the assignments were not designed for collaborative work. It was believed that these two situations would not arise in the groups under study in the 1999 spring semester course due to the nature of the assignments and the directions concerning the use of the technology.

There were other findings, some unexpected, from this pilot study as well. One had to do with the nature of group membership. When the summer course began, the

instructor placed the students into on-line communication groups of three. When it seemed to the instructor that these groups were not working, he abandoned the small groups in favor of larger ones. The instructor's intuition proved correct: when the groups of three were disbanded, the phase level of the communications increased almost immediately. Also, with only three in the group, it seemed as if each group had one member constantly answering the questions of the other two. It would seem, therefore, that group size must be larger than three in order to have meaningful on-line dialogue between group members.

Another discovery, one less surprising, was the communication phase levels of the individual members. Some class members rarely if ever moved passed Phase I; they were constantly asking questions, or making interpersonal comments, but rarely offered constructive suggestions in relation to the on-line homework problems. Other class members moved through the first three phase levels with regularity, although it was rare for any member to move beyond Phase III in the on-line communications.

The rating of all the messages in the 1999 spring semester course was done by the researcher. However, for the purpose of establishing inter-rater reliability, another individual rated a substantial section of the communication. The researcher trained the second individual in the proper use of the instrument. The researcher and second rater met on a weekly basis to compare their ratings of the on-line messages; any differences were discussed and a score for those messages was agreed upon. After three weeks, the researcher and the second rater scored 121 messages to establish inter-rater reliability. The Pearson's  $r$  was calculated at .8261, with a  $p$ -value less than .001. Therefore, the

messages scored by the researcher and the messages scored by the rater were correlated. It was concluded that the researcher was using the instrument in the appropriate manner, and reliability of measurement was established. In other words, the test of inter-rater reliability proved that the researcher was free from bias when rating the messages.

Also, the researcher performed a test-retest on a sample of seventy-five messages. The second rating took place approximately four months after the initial rating. The Pearson's  $r$  for this rating was calculated at .8119, with a  $p$ -value less than .001. Therefore, the scores given the messages during the retest were correlated to the scores given the messages during the initial rating. It was concluded that the researcher was consistent in his use of the instrument, and stability of the instrument was established.

### **Computer Attitudes and Anxiety**

Computer attitudes were measured during the second week of the study with the Computer Attitude Scale (CAS) developed by Loyd and Gressard (1984a). The CAS is an instrument that measures attitudes towards learning about and using computers. It is perhaps the most extensively used and tested scale of its type in use (Woodrow, 1991). The developers claim that this scale is "a convenient, reliable, and valid measure of computer attitudes, and that it can be confidently and effectively utilized in research and program evaluation contexts." (Woodrow, 1991) The instrument provides scores on four different scales: Computer Anxiety, Computer Confidence, Computer Liking and Computer Usefulness. Positively and negatively worded statements are included in each of the four areas. Alpha reliability coefficients calculated by the creators of the instrument for each of the four subgroups range from .86-.88, .87-.91, .88-.91, and .82

for each subscale, respectively with the total score having an alpha reliability of .95. An independent researcher found similar reliability coefficients (Woodrow, 1991). Each subscale consists of ten items. Students respond to the statements by selecting one of a set of four responses ranging from strongly agree to strongly disagree. Some sample items from the CAS are statements such as "Computers make me feel nervous and uncomfortable" or "Computers do not scare me at all". The correlations between the subscales range from .69 to .84. Scores can range from a low of 10 to a high of 40 on each of the subscales. In general, the higher the score, the more positive the attitude about computers. Any composite score above 90-95 indicates a neutral to positive attitude towards computers. In previous studies, it was found that gender played no significant role in computer attitudes (Loyd and Gressard, 1987), and that computer attitudes were significantly affected by computer experience (Loyd and Gressard, 1984b). A copy of the CAS can be found in Appendix A. Permission for its use can be found in Appendix G.

### **Prior Mathematical Achievement**

Prior achievement in mathematics was measured using the student's grade point average in mathematics. For the purposes of this study, the student's grade point average in mathematics was determined to be the cumulative average of all mathematics courses that student had completed that applied directly towards earning a degree in secondary mathematics education. No grades in remedial course work in mathematics were included in this average. Also, if a student had repeated a course because of a prior low

grade in that course, only the grade from the last time the course was taken was used to calculate the student's grade point average in mathematics.

### **Attitudes Towards Course and Towards the Two Treatments**

Finally, attitudes towards the course, the use of the on-line technology for communications, and use of technology in education were measured after the course through the use of a survey. Students were to respond to the statements in the survey by selecting one of a set of five responses. - strongly agree, slightly agree, neutral, slightly disagree, or strongly disagree. The survey was designed to allow students to reflect on what they perceived as the advantages and disadvantages communicating using MSUlink and the First Class Client software, and advantages and disadvantages associated with distance learning courses. The instrument was designed by the researcher, and deemed valid by the professor teaching the course, an expert in the field of distance learning and mathematics education. A copy of the instrument can be found in Appendix A.

### **Research Design**

The study examined the amount of communication and the phase level (as determined by the Interaction Analysis Model) of the communication that took place on-line between students in problem-solving groups in a geometry course for teachers. As described earlier, the students of the course were placed into four groups, with the on-campus students heterogeneously matched on mathematics grade point average, with gender as a secondary matching characteristic. Three of the groups consisted of on-campus students; one group of entirely off-campus students. The content covered by all

four groups was identical in scope and sequence. Students in all groups received instructional materials concerning the problem-solving tasks in the same manner - over the Internet/World Wide Web, and/or MSUlink through the First Class Client software program.

Student interactions for the group problem-solving activities, whether using the asynchronous communication environment or synchronous communication environment, were conducted through the Internet using MSUlink. MSUlink allowed the students to communicate interactively with each other in their group, with other groups (although this was a rare occurrence), and with the instructor. It also automatically records all bulletin board messages, and can also record the length of time each student is logged on to the system. It did not automatically record chat sessions, but students easily recorded them on the system by saving them as a message. MSUlink also allowed students to attach to their messages files from several different formats. This allowed students to show examples of their work using other software programs, such as the Geometers Sketchpad, Microsoft Word and Equation Editor, Non-Euclid, etc. This feature proved to be very valuable, assisting the students in their explanations of their work on the problem-solving tasks. At the beginning of the semester, all students were trained in the use of MSUlink.

All students were assessed in the same manner. For the collaborative group activities, a common grade was given to all students in the group, unless it was judged by the instructor that a group member did not participate in the activity. Also, all students

were given the exact same tests and scored with the same scoring rubric regardless of location (on or off campus).

There were several possible contaminating variables that had to be controlled. One was the problem of students who did not complete the course during the semester of study, or who consistently refused or could not participate in the group work activities. People who did not feel comfortable with technology may not wish to participate once they have been in the course for a brief time. Studies have shown that once students become familiar with the technology, they tend to become more willing to become active participants of the study (McHenry and Bozik, 1995; Yakimovicz and Murphy, 1995). Based on this, any student who wanted to drop early in the semester because of technology problems would have been first specially tutored on the use of the technology, and would have been encouraged to stay in the class. If they still wished to discontinue working, and group activities have begun (after the first two class weeks), that student's individual scores and ratings were eliminated from the study. Also, since it was a major requirement of the course that students participate in the group work activities, and since these activities were a major part of the course grade, it was hoped that these factors would assist those students who did stay in the course for its entirety to take an active role in the group work activities. However, participation in the group activities did not guarantee verbal participation in the on-line discussion of those group activities, despite the encouragement of the instructor. Two students dropped the course during the semester. One student dropped the course during the first week, so he had no data recorded for the purpose of this study. There was only one student who dropped the class

during the course of the semester. That student's communication and academic data was eliminated from the sample; her group contributions and individual activities were not included.

Another possible problem that was a concern was if the computer system would have shut down and been off-line for a considerable amount of time. If this had occurred and the groups could not have met on-line to complete a problem, then that activity along with any possible work completed on it up to that time would have been eliminated from the study. Fortunately, this did not happen. However there were occasional minor glitches in the system, which should be expected whenever working with technology. When the system was off-line for only a short amount of time, steps were taken to extend the deadline to allow students to complete their work.

Selection could have been a problem with the validity. There did exist the possibility that the groups, after being assigned, were different in ability levels at the beginning of the study. However, the study groups were assigned using matched samples on this variable; this hopefully alleviated the problem. Also, after the groups had been assigned but before the study on the group activities begun, an instrument (the Computer Attitude Scale) was given to the groups to determine if their comfort level and familiarity with the technology being used was appropriate. If a huge discrepancy existed between groups, they would have been restructured appropriately. The instructor, through his work with the students during the first two weeks, gathered formative data to determine if each student had the ability to complete the materials in the geometry course, and if all

the groups were approximately equal in ability. If there existed a discrepancy between groups in this area, the instructor would have restructured the groups appropriately.

Since the phase level of the communications were established through the use of human observation, the improper use of the instrument could be a threat to internal validity. To control this, more than one rater was used for part of the study, and the researcher re-rated a considerable section of dialogue several weeks after first rating it to establish inter-rater reliability and stability in use of the instrument.

A final possible threat to validity was the Hawthorne Effect, which is the tendency of subjects under study to act atypically because of their awareness of being studied, or because of novelty of the treatment. This could occur since the instructional medium was different than anything that most of the subjects had ever experienced. It was hoped that because of the age of the students (being more mature in general) and the length of the study (over the length of the course, and not for the first two weeks of the course), the effect would be minimized. However, like all of the above, it was acknowledged as a limitation of the study.

### **Statistical Hypotheses**

Ferguson (1981) states that it is a common convention to adopt significance levels of .05 or .01, and that it is also ordinary that an investigator may adopt, perhaps arbitrarily, a particular level of significance. For the purposes of this study, all hypotheses were tested at the .05 level. In most situations, a p-value was also reported with the test. The numbering of the hypotheses below reflect the numbering of the

general questions asked in Chapter 1. For example, all questions and hypotheses dealing with general question number 1 begin with a 1 followed by a dot, such as hypothesis 1.1.

Questions addressed in this study were stated in the form of null hypotheses. The reader is reminded that communication refers to any bulletin board (asynchronous) or chat room (synchronous) interaction that took place between group members while they were involved in the completion of the weekly problem-solving tasks. Phase level refers to the scores that could be given to each message or chat based upon the Interaction Analysis Model. Group refers to the four problem-solving groups in the course. Average communication score was calculated by dividing the total amount of the scored messages for each group or individual by the number of scored messages sent by that group or individual on any task. High level messages refers to the number of messages that were sent by an individual or group that were scored at phase levels three, four, or five. Percentage of high level messages was calculated by dividing the number of high level messages sent by a group or individual by the total number of messages sent by that group or individual on any task. Highest message level attained refers to the highest phase level attained by any member of a group during their work on a problem-solving task.

- 1.1) The communication phase levels were independent of whether the students were on campus or off campus.
- 1.2) The communication phase levels were independent of group membership.
- 2.1) There was no significant relationship between an individual's final test score and an individual's average communication score.

- 2.2) There was no significant relationship between an individual's average test score and an individual's average communication score.
- 2.3) There was no significant relationship between an individual's final test score and the number of high level messages for each individual.
- 2.4) There was no significant relationship between an individual's test average and the number of high level messages for each individual.
- 2.5) There was no significant relationship between an individual's final test score and the percentage of high level messages for each individual.
- 2.6) There was no significant relationship between an individual's test average and the percentage of high level messages for each individual.
- 2.7) There was no significant relationship between an individual's final test score and the total number of scored messages for that individual.
- 2.8) There was no significant relationship between an individual's test average and the total number of scored messages for that individual.
- 3.1) There was no significant relationship between the scores on the group tasks and the average communication score each group earned on that task.
- 3.2) There was no significant relationship between the scores on the group tasks and the number of scored messages each group had on each task.
- 3.3) There was no significant relationship between the scores on the group tasks and the number of high level messages recorded for each group on each task.
- 3.4) There was no significant relationship between the scores on the group tasks and the highest message level attained by each group for that task.

- 3.5) There was no significant relationship between the rank of each group task and the average communication score for each group earned on that task.
- 3.6) There was no significant relationship between the rank of each group task and the number of scored messages for each group on each task.
- 3.7) There was no significant relationship between the rank of each group task and the number of high level messages by each group for each task.
- 3.8) There was no significant relationship between the rank of each group task and the highest level message attained by each group for that task.
- 4.1) The average communication score within the problem-solving groups did not change over time.
- 4.2) The number of messages sent by each group did not change over time.
- 4.3) The total number of high level messages sent by each group did not change over time.
- 4.4) The percent of high level messages for each group did not change over time.
- 4.5) The highest level scored on each task for each group did not change over time.
- 5) Individual students did not change average communication levels (phases) over time.
- 6.1) There was no significant difference in the total number of messages between male and female students.
- 6.2) There was no significant difference in the average communication score between male and female students.

- 6.3) There was no significant difference in the total number of high level messages sent by male and female students.
- 6.4) There was not a significant difference in the percentage of high level messages sent by male and female students.
- 6.5) There was not a significant difference in the number of messages sent at each phase level between male and female students.
- 7.1) There was no significant difference in the mean test score between male and female students.
- 7.2) There was no significant difference on the final test score between male and female students.
- 8.1) There was no statistically significant relationship between the average communication score of the student and his or her comfort level and attitude about computers.
- 8.2) There was no statistically significant relationship between the number of scored messages for each student and his or her comfort level and attitude about computers.
- 8.3) There was no statistically significant relationship between the total number of high level messages for each student and his or her comfort level and attitude about computers.
- 9.1) There was no statistically significant relationship between individual achievement on the final test for each student and his or her comfort and attitude about computers.

- 9.2) There was no statistically significant relationship between individual achievement on the test average for each student and his or her comfort and attitude about computers.

### **Analysis of Data**

The hypotheses for this study were analyzed using three different software packages. Microsoft Excel was used for the hypotheses that were tested using ANOVA, the Chi-square test of association, or descriptive analysis. The hypotheses that involved a Pearson's test were analyzed using Minitab and/or Microsoft Excel. The hypotheses that involved trend analysis were tested using the Statistical Package for Social Sciences (SPSS). All line graphs were created using Microsoft Excel.

The independent variables in this study are 1) communication phase level, 2) gender, and 3) comfort level with the technology.

Hypotheses 1.1 and 1.2 were tested using a Chi-square test for association. For hypothesis 1.1, the variable tested was the total number of messages at each phase level for on campus students and off campus students. For hypothesis 1.2, the variable tested was the total number of messages at each phase level for each of the four problem-solving groups.

Hypotheses 2.1 through 2.8 were tested using Pearson's product moment correlation. The dependent variable for these hypotheses was an individual achievement variable (either average test score or final test score). The independent variable for each of these hypotheses was an individual communication phase level variable (either

average communication score, total number of high level messages sent, percentage of high level messages sent, or total messages sent).

Hypotheses 3.1 through 3.8 were tested using Pearson's product moment correlation. The dependent variable for these hypotheses was a group achievement variable (either the scores of each group task or the ranking of each group task). The independent variable for these hypotheses was a group communication phase level variable (either average communication score, total messages sent, total high level messages sent, or highest phase level attained).

Hypothesis 4.1 was tested using trend analysis, and analyzed through descriptive statistics. The factor for this hypothesis is the average communication score for each group, and the continuum underlying the factors was the time variable, in the form of task-by-task statistics. Hypotheses 4.2 through 4.5 were analyzed through descriptive statistics.

Hypothesis 5 was analyzed through descriptive statistics. The factor for this hypothesis is the average communication score of each individual, and the continuum underlying the factors was the time variable, in the form of task-by-task statistics.

Hypotheses 6.1 through 6.4 were tested using ANOVA. The independent variable for these hypotheses was the gender of the student (male or female). The dependent variable for these hypotheses was a communication variable, either the total number of messages, the average communication score, the total number of high level messages, or the percentage of high level messages. Hypothesis 6.5 was tested using a Chi-square test

for independence. The variable being tested was the number of messages sent by males and females at each phase level.

Hypotheses 7.1 and 7.2 were tested using ANOVA. The independent variable for these hypotheses was the gender of the student (male or female). The dependent variable for these hypotheses was an individual achievement variable; either the mean of the test scores, or the final test score.

Hypotheses 8.1 through 8.3 were tested using Pearson's product moment correlation. The independent variable for these hypotheses was the individual student's comfort and attitude towards computers, as measured by the Computer Attitude Scale developed by Loyd and Gressard (1984a). The dependent variable was an individual communication phase level variable, either the average communication score, total number of messages sent, or the total number of high level messages sent.

Hypotheses 9.1 and 9.2 were tested using Pearson's product moment correlation. The independent variable for these hypotheses was the individual student's comfort and attitude towards computers, as measured by the Computer Attitude Scale developed by Loyd and Gressard (1984a). The dependent variables for these hypotheses was an individual achievement variable, either the mean of the test scores, or the final test score.

### **Limitations and Delimitations**

The limitations of the study were as follows:

- 1) The population of the study consists solely of students who were enrolled in Modern Geometry or Geometry for Teachers.

- 2) The population of the study was drawn from students who enrolled in classes at Montana State University in the spring of 1999.
- 3) The period of study was for only one semester.
- 4) The size of the population of this study was relatively small. . .
- 5) Communication between members outside the allowed channels (i.e., communication other than through the use of the bulletin board or the chat room) was not completely controlled; but methods of controlling it were used, as outlined earlier.
- 6) Since the sample under study was the entire population of the class, selection could have been a delimitation. The attempt to control was outlined earlier.
- 7) Messages were given one score only, based upon the highest phase level attained in each message.
- 8) Messages were scored only for the person who sent the message, disregarding how many other people could have contributed to the contents of the message.

The delimitations of the study are as follows:

- 1) Any student whose personal history resulted in him or her not participating in the group activities for an extended period of time was excluded from the sample.
- 2) Students were placed into working groups by matching the students based on their cumulative grade point average in all college mathematics courses, with gender as a secondary matching characteristic.

## CHAPTER 3

### DATA ANALYSIS AND FINDINGS

#### Introduction

The data reported in this chapter are arranged into the following categories: communication - on campus vs. off campus, individual achievement and on-line communication, group achievement and on-line communication, changes in on-line communication patterns in groups over time, changes in on-line communication patterns in individuals over time, gender differences in on-line communication, gender differences in individual achievement, and incomplete data sets. To help control for possible extraneous variables, the groups were formed by placing the students in a group using heterogeneous matching on mathematical ability, so that the distribution of ability or talent with respect to the subject matter would be the same from group to group. It should be noted that since the number of students in this study was low relative to the number of hypotheses tested, Type I errors could have occurred in the testing of these hypotheses. Other statistics found during the course of this study not reported as hypotheses in this chapter can be found in Appendix F.

#### Communication - On Campus vs. Off Campus

Hypothesis 1.1: The communication phase levels were independent of whether the students were on campus or off campus.

Table 1 shows the number of messages scored at each phase level for the on-campus groups (combined) and the off-campus group. Table 2 shows the expected values for each phase level based upon location of each student (on campus or off campus). The expected values are the hypothesized or expected number of messages for each cell if the null hypothesis of statistical independence (between phase level and the location of the group, either on-campus or off-campus) were true. It should be noted that the data in Table 2 is rounded to the nearest whole number.

Table 1. Total messages scored at each phase level.

|            | Phase one | Phase two | Phase three | Phase four | Phase five |
|------------|-----------|-----------|-------------|------------|------------|
| On Campus  | 107       | 41        | 101         | 18         | 32         |
| Off Campus | 175       | 48        | 102         | 29         | 28         |

Table 2. Expected values for messages scored at each phase level.

|            | Phase one | Phase two | Phase three | Phase four | Phase five |
|------------|-----------|-----------|-------------|------------|------------|
| On Campus  | 124       | 39        | 89          | 21         | 26         |
| Off Campus | 158       | 50        | 114         | 26         | 34         |

Test: The chi-square test of independence resulted in a value of 9.8237, which rejects the null hypothesis at the .05 level with 4 degrees of freedom. The p-value obtained was .0435. By examining the tables, note that for phase one messages, the expected value was 17 messages higher for the on campus students, and 17 messages lower for the off campus students. For phase two messages, the expected values are very close to the actual values; there was only a difference of two, with on campus students having less than expected, off campus students more than expected. For phase three messages, the difference between expected number of messages and actual number of

messages was 12. Like the phase one messages, it was expected that the off campus students would have less messages at this phase level, and the on campus students more, than they actually had sent. With phase level four messages the difference was minimal between actual numbers of messages and the expected values. In this case, the difference was three, with the on campus students having three less than expected, the off campus students having three more than expected. For phase level five, the situation reversed itself. It was expected that the on campus students would have 26 messages at this level, when they actually had 32. It was expected that the off campus students would have 34 messages at this level, when they actually had 28. So the difference between expected and actual number of messages was only six, but it was expected that the off campus students would have more messages at this level (as with every level) than the on-campus students, when in fact this was not the case.

Result: The number of messages sent at certain phase levels was dependent upon whether the students were on campus students or off campus students.

Hypothesis 1.2: The communication phase levels were independent of group membership.

Table 3 shows the number of messages scored at each phase level for each of the four problem-solving groups (referred to as the Red Group, the Blue Group, the Green Group, and the Yellow Group). Table 4 shows the expected values for each phase level based upon group membership. The expected values are the hypothesized or expected number of messages for each cell if the null hypothesis of statistical independence

(between phase level and group) were true. It should be noted that the data in Table 4 is rounded to the nearest whole number.

Table 3. Number of messages scored at each phase level for each group.

|        | Phase one | Phase two | Phase three | Phase four | Phase five |
|--------|-----------|-----------|-------------|------------|------------|
| Red    | 18        | 9         | 9           | 3          | 1          |
| Blue   | 57        | 26        | 73          | 13         | 16         |
| Green  | 33        | 6         | 18          | 1          | 16         |
| Yellow | 176       | 47        | 102         | 29         | 28         |

Table 4. Expected values of number of messages scored for each group.

|        | Phase one | Phase two | Phase three | Phase four | Phase five |
|--------|-----------|-----------|-------------|------------|------------|
| Red    | 17        | 5         | 12          | 3          | 4          |
| Blue   | 77        | 24        | 55          | 12         | 17         |
| Green  | 31        | 10        | 22          | 5          | 7          |
| Yellow | 159       | 49        | 113         | 26         | 34         |

Test: The chi-square test of independence resulted in a value of 40.155, which rejects the null hypothesis at the .05 level with 4 degrees of freedom. The p-value obtained was less than .001. When examining the tables, differences can be found for the groups between the expected values and the actual values at some of the phase levels. Large discrepancies occur within the Blue and Yellow groups for phase 1 messages; the Blue group had less than was expected, the Yellow group had more than was expected. For phase 2 messages, the differences between the actual values and expected values are not great, although both the Red group and Green group have what could be considered a large discrepancy, when comparing the total number of messages sent at this level. For phase 3 messages, the largest difference occurs within the Blue group, which has 18 more messages at this level than predicted. For phase four messages, most expected values

are close to the actual number of messages; the exception to this would be the Green group, which showed a significant difference between expected number of messages (five) and actual number of messages (one) at this phase level. Finally, for phase five messages, the Green group shows a substantial difference between the actual number of messages (sixteen) and the predicted number (seven).

Result: The number of messages sent at certain phase levels was dependent upon group membership.

### **Individual Achievement and On-line Communication**

The hypotheses in this section (hypotheses 2.1 through 2.8) were tested for all students on an individual level, disregarding their problem-solving group affiliation. Group data were not looked at in this section, only individual student data. Group data were analyzed in hypotheses 3.1 through 3.8.

Hypothesis 2.1: There was no significant relationship between an individual's final test score and an individual's average communication score.

Test: The Pearson's correlation returned a value of  $-.3161$ , with a p-value of  $.201$ . Therefore, hypothesis 2.1 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between an individual's final test score and an individual's average communication score.

Hypothesis 2.2: There was no significant relationship between an individual's average test score and an individual's average communication score.

Test: The Pearson's correlation returned a value of  $-.5428$  with a p-value of  $.02$ .  
Therefore, hypothesis 2.2 is rejected at  $\alpha = .05$ .

Result: There was a significant relationship between an individual's average test score and an individual's average communication score. That relationship was an inverse relationship; the lower an individual's communication score, the higher the average test score.

Hypothesis 2.3: There was no significant relationship between an individual's final test score and the number of high level messages for each individual.

Test: The Pearson's correlation returned a value of  $-.2316$ , with a p-value of  $.355$ .  
Therefore, hypothesis 2.3 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between an individual's final test score and the number of high level messages for each individual.

Hypothesis 2.4: There was no significant relationship between an individual's test average and the number of high level messages for each individual.

Test: The Pearson's correlation returned a value of  $-.0575$ , with a p-value of  $.821$ .  
Therefore, hypothesis 2.4 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between an individual's test average and the number of high level messages for each individual.

Hypothesis 2.5: There was no significant relationship between an individual's final test score and the percentage of high level messages for each individual.

Test: The Pearson's correlation returned a value of  $-.3141$ , with a p-value of  $.204$ .  
Therefore, hypothesis 2.5 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between an individual's final test score and the percentage of high level messages for each individual.

Hypothesis 2.6: There was no significant relationship between an individual's test average and the percentage of high level messages for each individual...

Test: The Pearson's correlation returned a value of  $-.5421$ , with a p-value of  $.020$ . Therefore hypothesis 2.6 is rejected at  $\alpha = .05$ .

Result: There was a significant relationship between an individual's test average and the percentage of high level messages for each individual. That relationship was an inverse relationship; the lower the percentage of high level messages the individual sent, the higher the average test score.

Hypothesis 2.7: There was no significant relationship between an individual's final test score and the total number of scored messages for that individual.

Test: The Pearson's correlation returned a value of  $-.1915$ , with a p-value of  $.447$ . Therefore hypothesis 2.7 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between an individual's final test score and the total number of scored messages for that individual.

Hypothesis 2.8: There was no significant relationship between an individual's test average and the total number of scored messages for that individual.

Test: The Pearson's correlation returned a value of  $.0415$ , with a p-value of  $.870$ . Therefore hypothesis 2.8 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between an individual's test average and the total number of scored messages for that individual.

### **Group Achievement and On-line Communication**

Hypothesis 3.1: There was no significant relationship between the scores on the group tasks and the average communication score each group earned on that task.

Test: The Pearson's correlation returned a value of  $-.1545$ , with a p-value of  $.317$ .  
Therefore hypothesis 3.1 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between the scores on the group tasks and the average communication score each group earned on that task.

Hypothesis 3.2: There was no significant relationship between the scores on the group tasks and the number of scored messages each group had on each task.

Test: The Pearson's correlation returned a value of  $.0912$ , with a p-value of  $.556$ .  
Therefore hypothesis 3.2 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between the scores on the group tasks and the number of scored messages each group had on each task.

Hypothesis 3.3: There was no significant relationship between the scores on the group tasks and the number of high level messages recorded for each group on each task.

Test: The Pearson's correlation returned a value of  $-.020$ , with a p-value of  $.899$ .  
Therefore hypothesis 3.3 is not rejected at  $\alpha = .05$

Result: There was no significant relationship between the scores on the group tasks and the number of high level messages recorded for each group on each task.

Hypothesis 3.4: There was no significant relationship between the scores on the group tasks and the highest message level attained by each group for that task.

Test: The Pearson's correlation returned a value of  $-.0287$ , with a p-value of  $.854$ .  
Therefore hypothesis 3.4 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between the scores on the group tasks and the highest message level attained by each group for that task.

Hypothesis 3.5: There was no significant relationship between the rank of each group task and the average communication score for each group earned on that task.

Test: Pearson's correlation returned a value of  $.1882$ , with a p-value of  $.221$ .  
Therefore, hypothesis 3.5 is not rejected at  $\alpha = .05$ .

Result: There was no significant relationship between the rank of each group task and the average communication score for each group earned on that task.

Hypothesis 3.6: There was no significant relationship between the rank of each group task and the number of scored messages for each group on each task.

Test: The Pearson's correlation returned a value of  $.5092$ , with a p-value of less than  $.001$ . Therefore, hypothesis 3.6 is rejected at  $\alpha = .05$ .

Result: There was a significant relationship between the rank of each group task and the number of scored messages for each group on each task. This relationship was a positive relationship; in general, the higher the number of scored messages for each group on the task, the higher the ranking of that task.

Hypothesis 3.7: There was no significant relationship between the rank of each group task and the number of high level messages by each group for each task.

Test: The Pearson's correlation returned a value of  $.535$ , with a p-value of less than  $.001$ . Therefore hypothesis 3.7 is rejected at  $\alpha = .05$ .

Result: There was a significant relationship between the rank of each group task and the number of high level messages by each group for each task. That relationship was a positive relationship; in general, the greater the number of high level messages sent by each group for each task, the higher the rank of that task.

Hypothesis 3.8: There was no significant relationship between the rank of each group task and the highest level message attained by each group for that task.

Test: The Pearson's correlation returned a value of .3601, with a p-value of .016. Therefore hypothesis 3.8 is rejected at  $\alpha = .05$ .

Result: There was a significant relationship between the rank of each group task and the highest level message attained by each group for that task. In general, the higher the score on the highest level message attained by each group for a task, the higher the rank of that task.

### **Changes in On-line Communication Patterns among Groups Over Time**

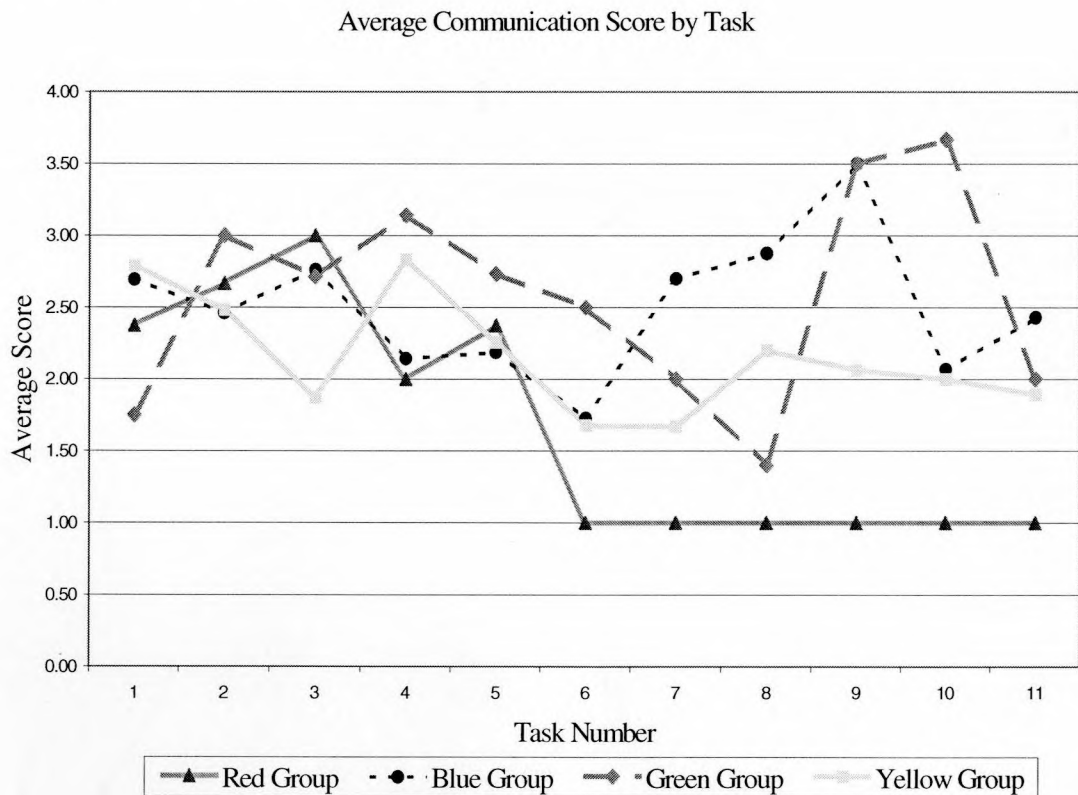
Hypothesis 4.1: The average communication score within the problem-solving groups did not change over time.

Table 5 on the next page shows the average communication score on each task for the four groups. The four groups were named the Red Group, the Blue Group, the Green Group, and the Yellow Group. The Yellow Group was the group whose members consisted solely of off campus students. Figure 1 shows a line graph of the information found in Table 5.

Table 5. Average communication score by task.

|         | Red Group | Blue Group | Green Group | Yellow Group |
|---------|-----------|------------|-------------|--------------|
| Task 1  | 2.38      | 2.69       | 1.75        | 2.79         |
| Task 2  | 2.67      | 2.46       | 3.00        | 2.48         |
| Task 3  | 3.00      | 2.76       | 2.71        | 1.87         |
| Task 4  | 2.00      | 2.14       | 3.14        | 2.83         |
| Task 5  | 2.38      | 2.19       | 2.73        | 2.26         |
| Task 6  | 1.00      | 1.73       | 2.50        | 1.68         |
| Task 7  | 1.00      | 2.70       | 2.00        | 1.67         |
| Task 8  | 1.00      | 2.88       | 1.40        | 2.20         |
| Task 9  | 1.00      | 3.50       | 3.50        | 2.06         |
| Task 10 | 1.00      | 2.07       | 3.67        | 2.00         |
| Task 11 | 1.00      | 2.43       | 2.00        | 1.89         |

Figure 1. Average communication score by task.



Test: The analysis of the average communication scores indicated the following.

The Red Group's average communication score decreased as time went on. Trend

analysis of the data showed that there exists a significant linear trend among the means ( $F = 18.491$ ,  $p < .001$ ). This, along with the trend equation ( $y = -.2083x + 2.924$ ) is enough to conclude that the Red Group did change phase levels through the semester, and that change was a decrease in average communication score. The Blue Group's average communication score increased only slightly overall, not enough to indicate a significant change from task 1 to task 11. The Green Group's average communication score also increased over time, but the increase was very slight and not significant. Trend analysis for both the Green group and the Blue Group did not find any significant trends. The Yellow Group's average communication score decreased over time. Trend analysis showed that there exists a significant linear trend ( $F = 10.064$ ,  $p = .002$ ) in the data. The decrease in average communication score should be considered significant, given the trend equation of  $y = -.07x + 2.5772$ .

Result: The Red Group decreased in average communication score (phase levels) through task 1 through 11. The Yellow Group also significantly decreased in average communication score, although the decrease was not nearly as sharp as the Red Group. The Blue Group and the Green Group both increased their average communication score throughout the semester. However this increase was not significant; therefore, it is judged that both groups did not change phase level throughout the course

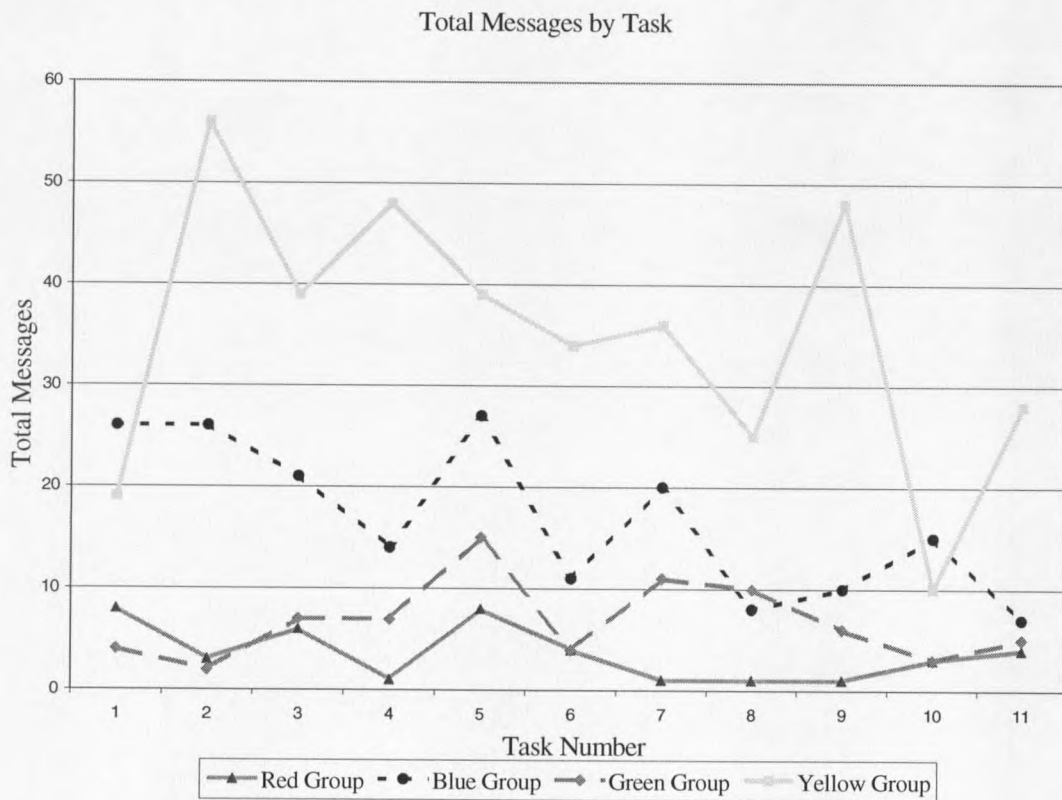
Hypothesis 4.2: The number of messages sent by each group did not change over time.

On the next page, Table 6 shows the number of messages sent by each group for each task. Figure 2 displays this information in a line graph.

Table 6. Number of messages per task sent by each group.

|         | Red Group | Blue Group | Green Group | Yellow Group |
|---------|-----------|------------|-------------|--------------|
| Task 1  | 8         | 26         | 4           | 19           |
| Task 2  | 3         | 26         | 2           | 56           |
| Task 3  | 6         | 21         | 7           | 39           |
| Task 4  | 1         | 14         | 7           | 48           |
| Task 5  | 8         | 27         | 15          | 39           |
| Task 6  | 4         | 11         | 4           | 34           |
| Task 7  | 1         | 20         | 11          | 36           |
| Task 8  | 1         | 8          | 10          | 25           |
| Task 9  | 1         | 10         | 6           | 48           |
| Task 10 | 3         | 15         | 3           | 10           |
| Task 11 | 4         | 7          | 5           | 28           |

Figure 2. Number of messages per task sent by each group.



Analysis: With the exception of the Green Group, all groups display a decreasing trend in the total number of messages sent per task. The Green Group shows a slight increasing trend, peaking during the middle of the semester. The total number of messages sent by the Red Group for each task decreased over time, dropping dramatically after mid semester. The Blue Group's total messages decreased over time as well, although the decrease was not as precipitous as the Red Group's when compared to the total number of messages sent for each task. The Yellow Group's total number of messages also decreased over time. However, the decrease is not as steep as the Blue or Red Group's decrease, when compared to the total number of messages sent by the group. It is also interesting to note that, with very few exceptions, the Yellow Group sent the most messages for each task, followed by the Blue Group, then the Green Group, with the Red Group sending the least amount of messages. This pattern is broken only twice after the second task, making it seem that each group developed their own style of communicating when working on the problem-solving tasks.

Result: The Green Group's total number of messages stayed fairly constant throughout the semester. It is judged that the number of messages sent by the Green Group did not change from task 1 to task 11. The other three groups did significantly decrease in the amount of messages sent during the semester.

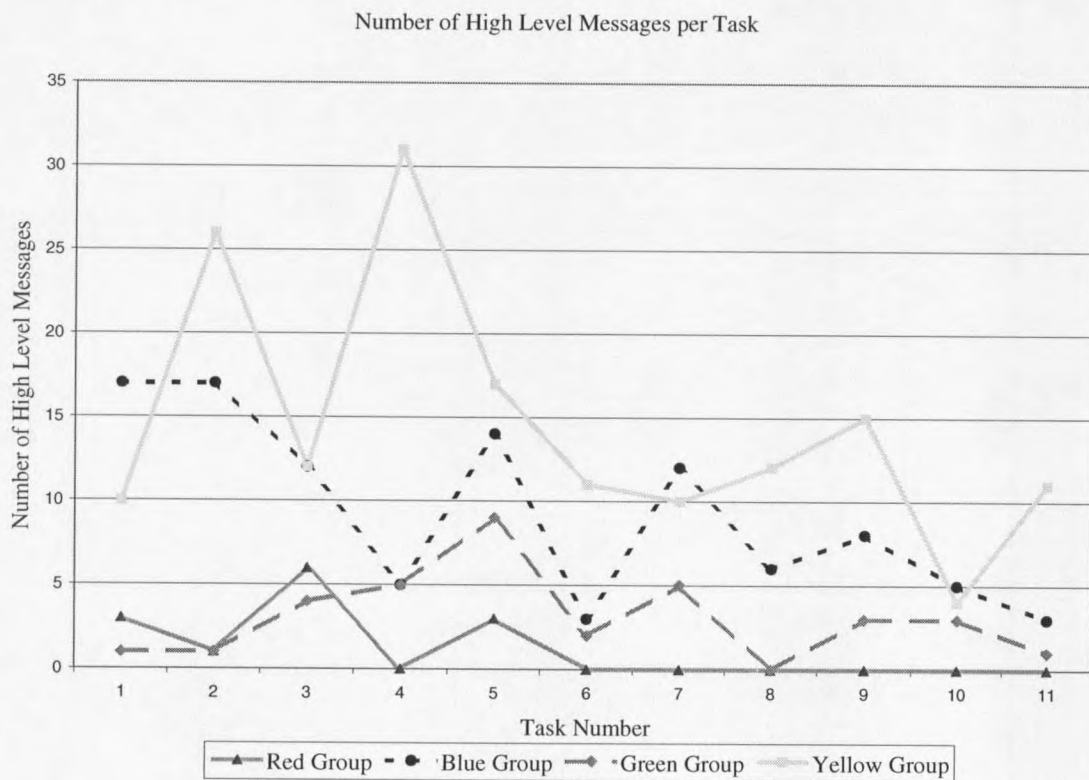
Hypothesis 4.3: The total number of high level messages sent by each group did not change over time.

Table 7 on the next page shows the number of high level messages sent by each group for each task. Figure 3 displays this information in a line graph.

Table 7. Total number of high level messages per task for each group.

|         | Red Group | Blue Group | Green Group | Yellow Group |
|---------|-----------|------------|-------------|--------------|
| Task 1  | 3         | 17         | 1           | 10           |
| Task 2  | 1         | 17         | 1           | 26           |
| Task 3  | 6         | 12         | 4           | 12           |
| Task 4  | 0         | 5          | 5           | 31           |
| Task 5  | 3         | 14         | 9           | 17           |
| Task 6  | 0         | 3          | 2           | 11           |
| Task 7  | 0         | 12         | 5           | 10           |
| Task 8  | 0         | 6          | 0           | 12           |
| Task 9  | 0         | 8          | 3           | 15           |
| Task 10 | 0         | 5          | 3           | 4            |
| Task 11 | 0         | 3          | 1           | 11           |

Figure 3. Total number of high level messages per task for each group.



Analysis: The Red Group had a decrease in total high level messages during the course of the semester, but it is apparent that the group did not communicate on-line at

high levels very often throughout the study. The other groups indicate trends similar to what was found in the total number of messages data. The Green Group's number of high level messages seemed to be increasing until roughly mid-semester; then the trend reverses itself, and they finish roughly at the same point as where they started. The Blue Group and Yellow Group decrease in total number of high level messages throughout the semester. Also, the pattern that was noticeable for the total number of messages - that of the Yellow group having the highest amount of messages, followed by the Blue Group, the Green Group, and the Red Group, respectively - seems to hold here as well.

Result: The Green Group increased the number of high level messages during the first part of the semester, with the totals declining slightly after that. Overall, this group showed no significant change in total number of high level messages from the beginning to the end of the semester. The other three groups demonstrate a significant decreasing trend in the number of high level messages sent throughout the semester.

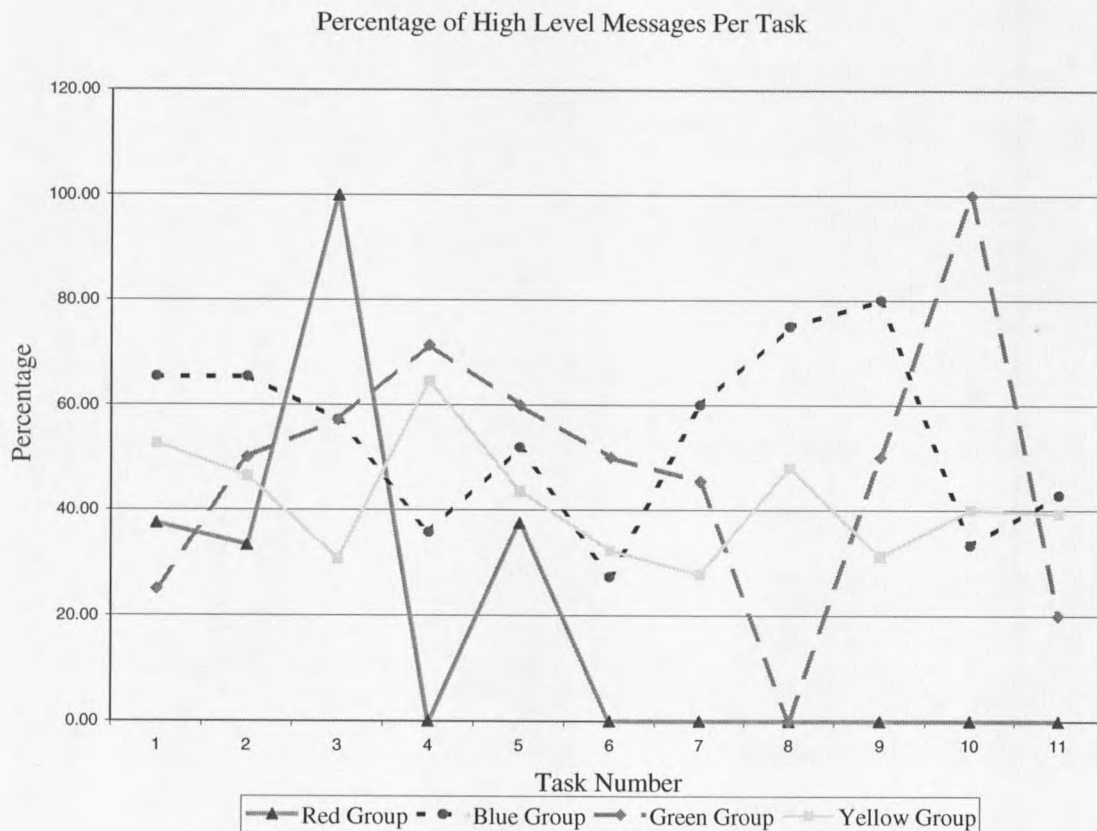
Hypothesis 4.4: The percent of high level messages for each group did not change over time.

On the next page, Table 8 shows the percentage of high level messages by each group for each task. Figure 4 displays this information in a line graph.

Table 8. Percentage of high level messages per task for each group.

|         | Red Group | Blue Group | Green Group | Yellow Group |
|---------|-----------|------------|-------------|--------------|
| Task 1  | 37.50     | 65.38      | 25.00       | 52.63        |
| Task 2  | 33.33     | 65.38      | 50.00       | 46.43        |
| Task 3  | 100.00    | 57.14      | 57.14       | 30.77        |
| Task 4  | 0.00      | 35.71      | 71.43       | 64.58        |
| Task 5  | 37.50     | 51.85      | 60.00       | 43.59        |
| Task 6  | 0.00      | 27.27      | 50.00       | 32.35        |
| Task 7  | 0.00      | 60.00      | 45.45       | 27.78        |
| Task 8  | 0.00      | 75.00      | 0.00        | 48.00        |
| Task 9  | 0.00      | 80.00      | 50.00       | 31.25        |
| Task 10 | 0.00      | 33.33      | 100.00      | 40.00        |
| Task 11 | 0.00      | 42.86      | 20.00       | 39.29        |

Figure 4. Percentage of high level messages per task for each group.



Analysis: The Red Group showed a large decrease in percentage of high level messages. In addition, the percentage fluctuates wildly from week to week during the

first part of the semester. However, given that the number of high level messages sent by the Red Group was so small, this finding must be judged accordingly. The Blue Group's percentage of high level messages declined slightly throughout the semester until roughly mid semester. The percentage then started to increase, with a decline again in the last two weeks. The Green Group's percentage of high level messages increased during the first part of the semester, then began to decrease. Overall, the percent was basically stable and predictable to a certain degree. However, after about mid-semester, their percentage began to fluctuate wildly. This could be partially due to the fact that the group began to show a decrease in the overall number of messages sent. The Yellow Group's data indicates a relatively stable percentage of high level messages throughout the semester, perhaps declining slightly.

Results: Given the small number of high level messages sent by the Red Group, it is difficult to conclude that the change in percentage of high level messages was significant. It is difficult to judge the changes in the Blue Group and Green Group as significant as well. Even though the percentages of high level messages increased dramatically for both at the end of the semester, the decline in the number of messages sent may account for this change. The Yellow Group demonstrated an overall decrease in percentage of high level messages from task 1 to task 11, although the percentage of high level messages among this group stayed relatively stable, and thus is considered not to show a significant change.

Hypothesis 4.5: The highest level scored on each task for each group did not change over time.

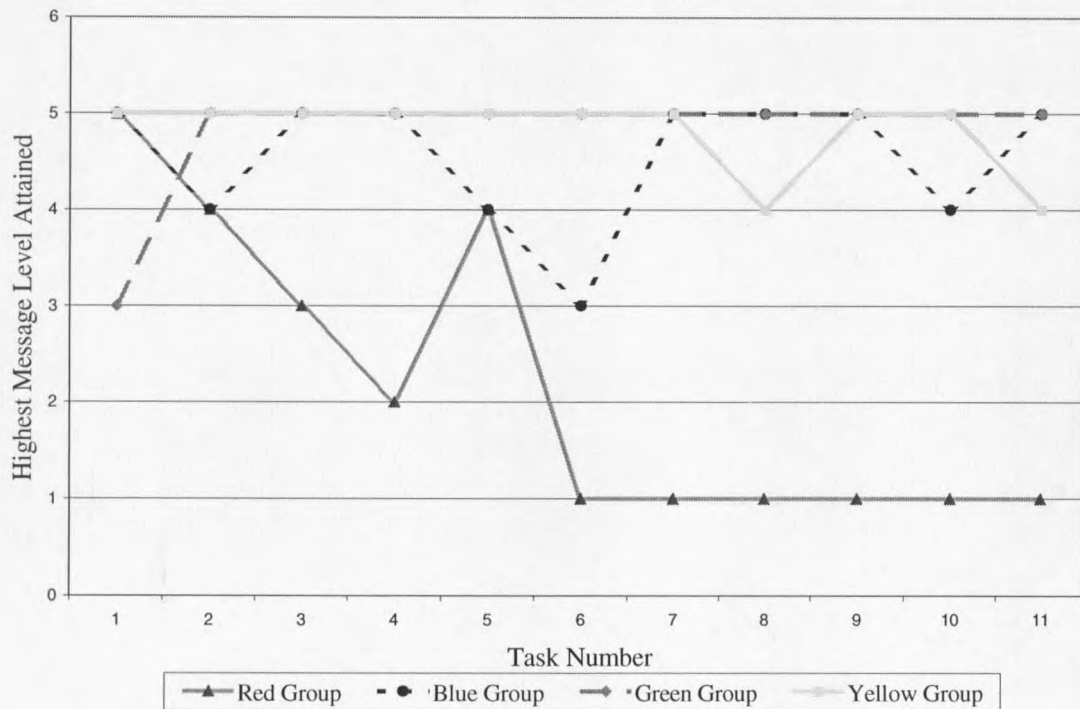
Table 9 shows the highest level scored on each task for each group. Figure 5 displays the information in a line graph.

Table 9. Highest message level attained on each task by each group.

|         | Red Group | Blue Group | Green Group | Yellow Group |
|---------|-----------|------------|-------------|--------------|
| Task 1  | 5         | 5          | 3           | 5            |
| Task 2  | 4         | 4          | 5           | 5            |
| Task 3  | 3         | 5          | 5           | 5            |
| Task 4  | 2         | 5          | 5           | 5            |
| Task 5  | 4         | 4          | 5           | 5            |
| Task 6  | 1         | 3          | 5           | 5            |
| Task 7  | 1         | 5          | 5           | 5            |
| Task 8  | 1         | 5          | 5           | 4            |
| Task 9  | 1         | 5          | 5           | 5            |
| Task 10 | 1         | 4          | 5           | 5            |
| Task 11 | 1         | 5          | 5           | 4            |

Figure 5. Highest message level attained on each task by each group.

Highest Message Level Attained on Each Task



Analysis: The Red Group decreased in highest message level for each task from task 1 to task 11. The other three groups remained relatively stable in having the highest possible phase level attained for each task, with an occasional fluctuation into a lower phase level.

Result: The Red Group's overall highest message level for each task decreased significantly over time, changing roughly at mid-semester. The other three groups did not significantly change highest message level attained for each over time.

### **Changes in On-line Communication Patterns among Individuals Over Time**

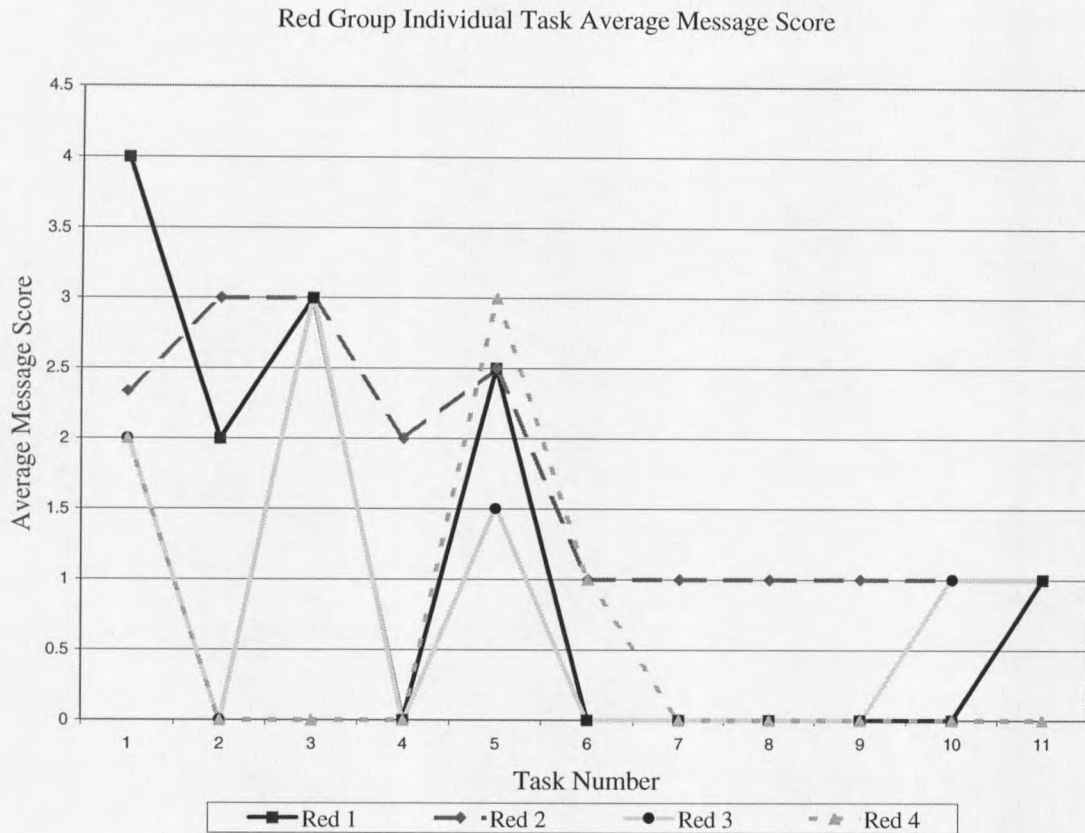
Hypothesis 5: Individual students did not change average communication levels (phases) over time.

The average communication level for each task for the individual members of the Red Group is illustrated in Table 10. Figure 6 displays the information in a line graph on the next page.

Table 10: Individual Red Group member's average communication score for each task.

|         | Red 1 | Red 2 | Red 3 | Red 4 |
|---------|-------|-------|-------|-------|
| Task 1  | 4.00  | 2.33  | 2.00  | 2.00  |
| Task 2  | 2.00  | 3.00  | 0.00  | 0.00  |
| Task 3  | 3.00  | 3.00  | 3.00  | 0.00  |
| Task 4  | 0.00  | 2.00  | 0.00  | 0.00  |
| Task 5  | 2.50  | 2.50  | 1.50  | 3.00  |
| Task 6  | 0.00  | 1.00  | 0.00  | 1.00  |
| Task 7  | 0.00  | 1.00  | 0.00  | 0.00  |
| Task 8  | 0.00  | 1.00  | 0.00  | 0.00  |
| Task 9  | 0.00  | 1.00  | 0.00  | 0.00  |
| Task 10 | 0.00  | 1.00  | 1.00  | 0.00  |
| Task 11 | 1.00  | 1.00  | 1.00  | 0.00  |

Figure 6. Individual Red Group member's average communication score for each task.



Test: Analysis performed on the members of the Red Group indicated that all members of the Red Group showed a decrease in average message score from task 1 to task 11. However, due to the relative small amount of messages sent by each member of the Red Group, any conclusions drawn from their analysis must be made with caution. The exception to this could be Red 2, who send messages every week. Red 2 started the semester with an average message score between 2 and 3 for the first five tasks, then regressed to sending out just Phase 1 messages for the duration of the semester. It can be judged that Red 2 significantly decreased in average message score during the semester.

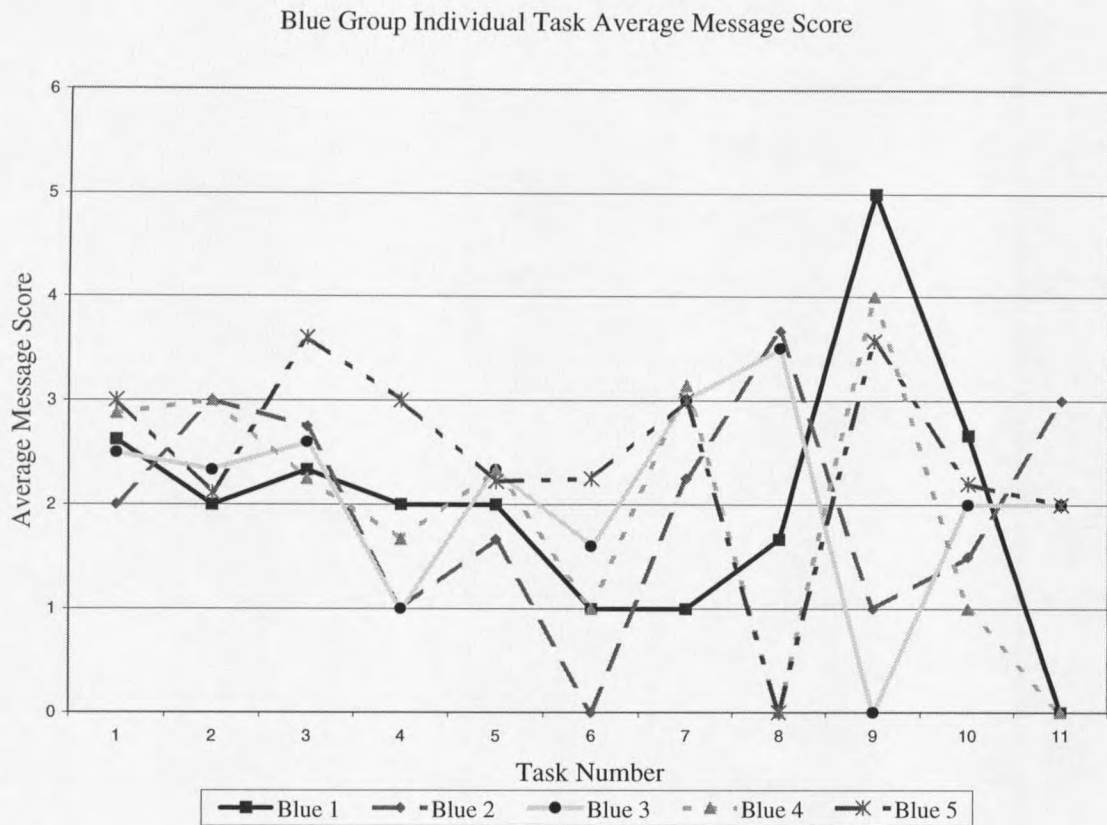
Result: All members of the Red Group show a decreasing trend in overall average message score. For Red 2, it can be determined with relative confidence that this individual changed phase level in communication throughout the semester. This is due to the fact that unlike other members of the Red Group, Red 2 continued to communicate each week, albeit at the lowest phase level for the latter half of the semester. However, any speculation on the change in average communication for the other members of this group must be viewed with caution. Red 1 had six weeks without a scored message, as did Red 3. Red 4 had eight weeks without any scored messages. Therefore, although the decrease in average message score seemed significant for the other members, it is judged that any conclusions made are speculative at best due to the lack of data.

The average message score for each task for individuals in the Blue Group are shown in Table 11. On the next page, Figure 7 displays the information in a line graph.

Table 11: Individual Blue Group member's average communication score for each task.

|         | Blue 1 | Blue 2 | Blue 3 | Blue 4 | Blue 5 |
|---------|--------|--------|--------|--------|--------|
| Task 1  | 2.63   | 2.00   | 2.50   | 2.88   | 3.00   |
| Task 2  | 2.00   | 3.00   | 2.33   | 3.00   | 2.11   |
| Task 3  | 2.33   | 2.75   | 2.60   | 2.25   | 3.60   |
| Task 4  | 2.00   | 1.00   | 1.00   | 1.67   | 3.00   |
| Task 5  | 2.00   | 1.67   | 2.33   | 2.33   | 2.22   |
| Task 6  | 1.00   | 0.00   | 1.60   | 1.00   | 2.25   |
| Task 7  | 1.00   | 2.25   | 3.00   | 3.14   | 3.00   |
| Task 8  | 1.67   | 3.67   | 3.50   | 0.00   | 0.00   |
| Task 9  | 5.00   | 1.00   | 0.00   | 4.00   | 3.57   |
| Task 10 | 2.67   | 1.50   | 2.00   | 1.00   | 2.20   |
| Task 11 | 0.00   | 3.00   | 2.00   | 0.00   | 2.00   |

Figure 7: Individual Blue Group member's average communication score for each task.



Test: Analysis found no significant trend, either increasing or decreasing, for members of the Blue Group that would model the data. This can be seen in the graph above; no one person has a discernable pattern in their mean message score. A case could be made for stating Blue 5 showed an overall increase. But given that the average message score remained fairly constant for the first 8 tasks (even decreasing slightly), with an increase shown in only tasks 9 and 10, it is judged that this member did not change communication phase levels over time. By looking at the data and the graph, other interesting facts are noticed. For the first few tasks, the average message score for all five members is fairly close. As the semester continues, the spread of the average

message score among the five members grows rapidly. The change of each individual's average message score from task to task at the end of the semester fluctuates wildly as well, while those changes were not as pronounced earlier. Also, it is interesting to note that one member (Blue 5) is at the top or near the top for almost every task in average message score. It is also interesting that there were a total of six instances of an individual sending no messages for a given week; yet each member of the group had at least one, and they did not usually occur during the same week. It seems to indicate that certain members would "take a week off" from working on the group task, at least from conducting any communication or work on-line.

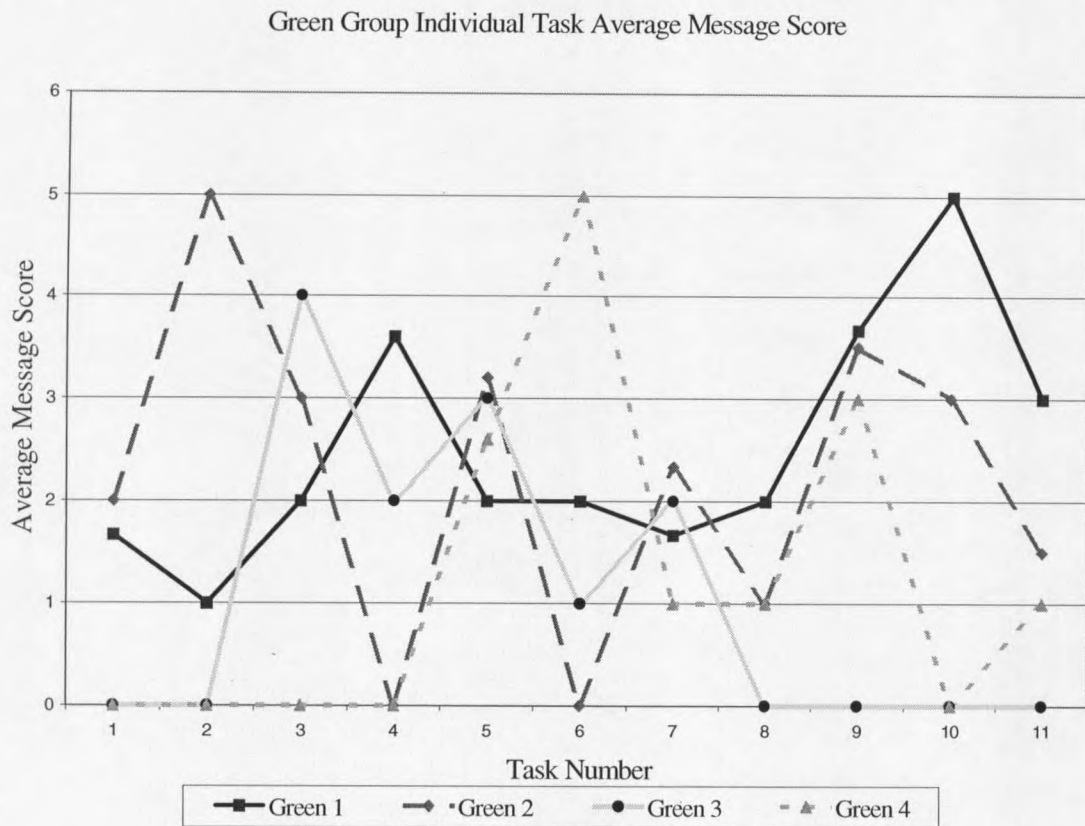
Result: Analysis found no significant trends among the five members of the Blue group. Judging from the graph and the data table, the average message score for the members does not change greatly during the semester, discounting the tasks with a score of zero.

The average message score for each task for individuals in the Green Group are shown in Table 12. On the next page, Figure 8 displays the information in a line graph.

Table 12: Individual Green Group member's average communication score for each task.

|         | Green 1 | Green 2 | Green 3 | Green 4 |
|---------|---------|---------|---------|---------|
| Task 1  | 1.67    | 2.00    | 0.00    | 0.00    |
| Task 2  | 1.00    | 5.00    | 0.00    | 0.00    |
| Task 3  | 2.00    | 3.00    | 4.00    | 0.00    |
| Task 4  | 3.60    | 0.00    | 2.00    | 0.00    |
| Task 5  | 2.00    | 3.20    | 3.00    | 2.60    |
| Task 6  | 2.00    | 0.00    | 1.00    | 5.00    |
| Task 7  | 1.67    | 2.33    | 2.00    | 1.00    |
| Task 8  | 2.00    | 1.00    | 0.00    | 1.00    |
| Task 9  | 3.67    | 3.50    | 0.00    | 3.00    |
| Task 10 | 5.00    | 3.00    | 0.00    | 0.00    |
| Task 11 | 3.00    | 1.50    | 0.00    | 1.00    |

Figure 8. Individual Green Group member's average communication score for each task.



Test: Analysis found no significant increasing or decreasing trends in the data for the members of the Green Group. Due to the lack of messages sent by two of the members (Green 3 at the end of the semester, and Green 4 at the beginning of the semester), it is difficult to judge if they changed phase levels during the course of the semester. It appears that Green 1 had an overall increase in phase level during the semester, while Green 2 seemed to decrease in average message score throughout the semester (even when discounting the two weeks of no communication). However, both remained fairly constant throughout the semester in their average messages score.

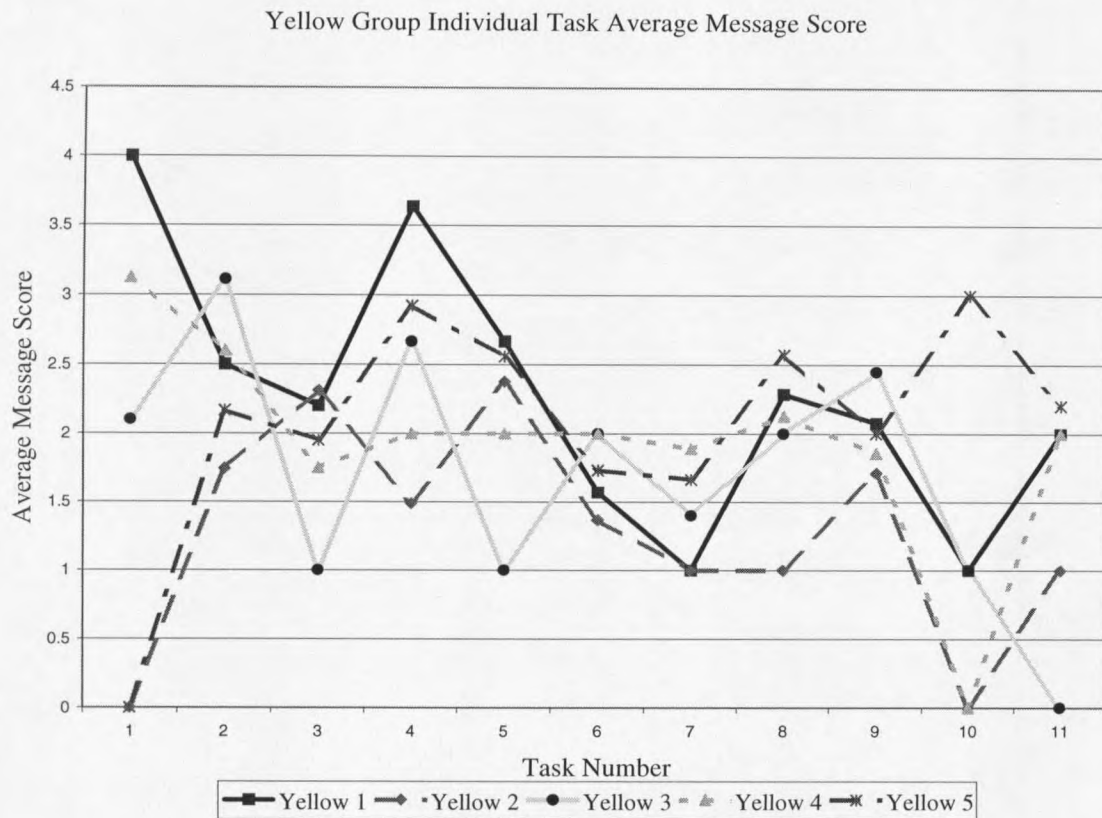
Result: Descriptive analysis indicates that the average message score of Green 1 shows a increasing trend throughout the semester, while Green 2 shows a slight decrease overall from task 1 to task 11. However, in both cases it is believed that the trends are not significant enough to believe that the phase level of either Green 1 or Green 2 changed during the semester. It is difficult if not impossible to judge any change in communication phase level for Green 3 or Green 4 due to the lack of messages sent by these members of the Green Group.

The average message score for each task for individuals in the Yellow Group are shown in Table 13. On the next page, Figure 9 displays the information in a line graph.

Table 13. Individual Yellow Group member's average communication score for each task.

|         | Yellow 1 | Yellow 2 | Yellow 3 | Yellow 4 | Yellow 5 |
|---------|----------|----------|----------|----------|----------|
| Task 1  | 4.00     | 0.00     | 2.10     | 3.13     | 0.00     |
| Task 2  | 2.50     | 1.75     | 3.11     | 2.60     | 2.17     |
| Task 3  | 2.20     | 2.31     | 1.00     | 1.75     | 1.95     |
| Task 4  | 3.64     | 1.49     | 2.67     | 2.00     | 2.92     |
| Task 5  | 2.67     | 2.38     | 1.00     | 2.00     | 2.56     |
| Task 6  | 1.57     | 1.37     | 2.00     | 2.00     | 1.73     |
| Task 7  | 1.00     | 1.00     | 1.40     | 1.89     | 1.67     |
| Task 8  | 2.29     | 1.00     | 2.00     | 2.13     | 2.57     |
| Task 9  | 2.08     | 1.71     | 2.44     | 1.86     | 2.00     |
| Task 10 | 1.00     | 0.00     | 1.00     | 0.00     | 3.00     |
| Task 11 | 2.00     | 1.00     | 0.00     | 2.00     | 2.20     |

Figure 9. Individual Yellow Group member's average communication score for each task.



Test: Analysis of the data indicated that Yellow 1 and Yellow 4 changed average communication phase levels during the semester, with the change being a decrease in average communication score. No significant trends were found among the other three members. Viewing both the data in the table and the graph, it appears that Yellow 2, Yellow 3, and Yellow 5 remained relatively stable in their average message score, although Yellow 2 and Yellow 3 show a slight decrease, and Yellow 5 shows a slight increase from task 1 to task 11. It should be noted that Yellow 2 and Yellow 5 have a score of zero for task 1 because they were not members of the class during task 1; they added the course after the completion of task one. It is interesting to note that no one

member maintained a pattern of having the highest average message score, and each member did have the highest average for at least one task. It is also interesting to see that one member scored higher than the others at the beginning of the semester, while another member scored consistently higher than the others at the end of the semester.

Result: Analysis indicated that Yellow 1 had a significant decreasing trend; therefore it is judged that Yellow 1 did change phase levels during the semester, and the change was a decreasing one. The analysis for Yellow 4 also showed a significant trend that decreased. However, since it is unknown how much influence task 10 (a score of zero) has on this predictor, it is difficult to state with any certainty that Yellow 4 changed phase levels. The other three members did not demonstrate any significant linear, quadratic, or cubic trends; it is judged that they did not change phase levels.

### **Gender Differences in On-line Communication**

Hypothesis 6.1: There was no significant difference in the total number of messages between male and female students.

A summary of the ANOVA table is shown in table 14 on the next page.

Table 14. ANOVA for total number of scored messages by gender.

**SUMMARY**

| <i>Groups</i>            | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|--------------------------|--------------|------------|----------------|-----------------|
| Female Total<br>Messages | 8            | 316        | 39.5           | 1300.571        |
| Male Total<br>Messages   | 10           | 365        | 36.5           | 857.1667        |

**ANOVA**

| <i>Source of<br/>Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|--------------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups                 | 40        | 1         | 40        | 0.03805  | 0.84779        | 4.49399       |
| Within Groups                  | 16818.5   | 16        | 1051.15   |          |                |               |
| Total                          | 16858.5   | 17        |           |          |                |               |

Test: Based on the ANOVA, hypothesis 6.1 is not rejected. There was no significant difference in the total number of messages between male and female students.

Result: Although the average number of messages sent was slightly higher for female students, the difference in that average was not statistically significant.

Hypothesis 6.2: There was no significant difference between male and female students in the average communication score.

A summary of the ANOVA table is shown in Table 15 on the next page.

Table 15. ANOVA for average communication score by gender.  
SUMMARY

| <i>Groups</i>                | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|------------------------------|--------------|------------|----------------|-----------------|
| Female Average Communication | 8            | 18.9873    | 2.37341        | 0.06267         |
| Male Average Communication   | 10           | 22.3208    | 2.23208        | 0.07385         |

## ANOVA

| <i>Source of Variation</i> | <i>SS</i> | <i>Df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups             | 0.0887729 | 1         | 0.08877   | 1.28724  | 0.27326        | 4.49399       |
| Within Groups              | 1.1034123 | 16        | 0.06896   |          |                |               |
| Total                      | 1.1921852 | 17        |           |          |                |               |

Test: Based on the ANOVA, hypothesis 6.2 is not rejected. There was no significant difference in the average communication score of males and females.

Result: Although the average communication score was slightly higher for female students, the difference in average communication score between male and female students was not statistically significant.

Hypothesis 6.3: There was no significant difference in the total number of high level messages sent by male and female students.

Test: Based on the ANOVA, hypothesis 6.3 is not rejected. There was no significant difference between males and females in the number of high level messages sent.

A summary of the ANOVA table for this test is shown in Table 16 on the next page.

Table 16. ANOVA for high level messages by gender.

## SUMMARY

| <i>Groups</i>   | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|-----------------|--------------|------------|----------------|-----------------|
| Female Total HL | 8            | 148        | 18.5           | 258             |
| Male Total HL   | 10           | 161        | 16.1           | 185.6556        |

## ANOVA

| <i>Source of Variation</i> | <i>SS</i> | <i>Df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups             | 25.6      | 1         | 25.6      | 0.1178   | 0.73589        | 4.493998      |
| Within Groups              | 3476.9    | 16        | 217.3063  |          |                |               |
| Total                      | 3502.5    | 17        |           |          |                |               |

Result: Even though the table indicates that males sent on average more high level messages, that difference was not statistically significant.

Hypothesis 6.4: There was not a significant difference in the percentage of high level messages sent by male and female students.

A summary of the ANOVA table is shown in Table 17.

Table 17. ANOVA for percentage of high level messages by gender.

## SUMMARY

| <i>Groups</i>                 | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|-------------------------------|--------------|------------|----------------|-----------------|
| Female percent<br>HL messages | 8            | 367.9862   | 45.99828       | 99.2829         |
| Male percent<br>HL messages   | 10           | 436.7007   | 43.67007       | 118.458         |

## ANOVA

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups             | 24.09136  | 1         | 24.09136  | 0.218875 | 0.646207       | 4.493998      |
| Within Groups              | 1761.102  | 16        | 110.0689  |          |                |               |
| Total                      | 1785.194  | 17        |           |          |                |               |

Test: Based on the ANOVA, hypothesis 6.4 is not rejected. There was no significant difference in the percentage of high level messages sent by male and female students.

Result: Although the table indicated that females sent a higher percentage of high level messages than their male counterparts, this difference was not statistically significant.

Hypothesis 6.5: There was not a significant difference between male and female students in the number of messages sent at each phase level.

Table 18 shows the number of messages at each phase level recorded for all male and female students. Table 19 shows the expected values for each phase level based upon gender. The expected values are the hypothesized or expected number of messages for each cell if the null hypothesis of statistical independence (between phase level and gender, either male or female) were true. It should be noted that the data in Table 19 is rounded to the nearest whole number.

Table 18. Number of messages at each phase level for each gender.

|         | Phase Levels |     |       |      |      |
|---------|--------------|-----|-------|------|------|
|         | one          | two | three | four | five |
| Females | 122          | 46  | 91    | 22   | 35   |
| Males   | 162          | 42  | 111   | 24   | 26   |

Table 19. Expected number of messages at each phase level for each gender.

|         | Phase Levels |     |       |      |      |
|---------|--------------|-----|-------|------|------|
|         | one          | two | three | four | five |
| Females | 132          | 41  | 94    | 21   | 28   |
| Males   | 152          | 47  | 108   | 25   | 33   |

Test: The chi-square test for independence resulted in a value of 9.210644, which does not reject the null hypothesis at the .05 level with 4 degrees of freedom. The p-value obtained was .2215.

Result: There was no significant difference between male and female students in the number of messages sent at each phase level.

### **Gender Differences in Individual Achievement**

Hypothesis 7.1: There was no significant difference in the mean test score between male and female students.

Table 20 shows the results of the ANOVA test.

Table 20. ANOVA for mean test score by gender.

#### **SUMMARY**

| <i>Groups</i>          | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|------------------------|--------------|------------|----------------|-----------------|
| Female Test<br>Average | 8            | 696.5      | 87.0625        | 34.1026         |
| Male Test<br>Average   | 10           | 909        | 90.9           | 19.5444         |

#### **ANOVA**

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups             | 65.45069  | 1         | 65.4507   | 2.52572  | 0.13156        | 4.4939        |
| Within Groups              | 414.6187  | 16        | 25.9137   |          |                |               |
| Total                      | 480.0694  | 17        |           |          |                |               |

Test: Based on the ANOVA, hypothesis 7.1 is not rejected. There was no significant difference in mean test score between male and female students.

Result: There was no significant difference in the mean score on the tests between male and female students.

Hypothesis 7.2: There was no significant difference between male and female students on the final test grade.

Table 21 shows the result of the ANOVA test:

Table 21. ANOVA for final test scores by gender.

**SUMMARY**

| <i>Groups</i>   | <i>Count</i> | <i>Sum</i> | <i>Average</i> | <i>Variance</i> |
|-----------------|--------------|------------|----------------|-----------------|
| Female FT Score | 8            | 715        | 89.375         | 50.5536         |
| Male FT Score   | 10           | 953        | 95.3           | 9.34444         |

**ANOVA**

| <i>Source of Variation</i> | <i>SS</i> | <i>df</i> | <i>MS</i> | <i>F</i> | <i>P-value</i> | <i>F crit</i> |
|----------------------------|-----------|-----------|-----------|----------|----------------|---------------|
| Between Groups             | 156.025   | 1         | 156.025   | 5.69986  | 0.02965        | 4.49399806    |
| Within Groups              | 437.975   | 16        | 27.3734   |          |                |               |
| Total                      | 594       | 17        |           |          |                |               |

Test: Based on the ANOVA, hypothesis 7.2 is rejected. There was a significant difference in final test score between male and female students.

Result: Males and females scored differently on the final test, with males scoring significantly higher than females.

### **Incomplete Data Sets**

#### **Computer Attitudes and Anxiety**

In the original proposal for this study, the experimental design called for a comparison to be made between the student's average communication phase level and

their comfort and attitude using the computer, and a comparison of the student academic achievement and their comfort and attitude using the computer. The Computer Attitude Scale was to be administered to all students for use in these comparisons. However, due to difficulties in confidentially administering the test and limiting the administration to before the data for the rest of the study were to be taken, the scale was given to only those students who were on campus. In addition, not all on campus students participated in this survey due to illness during the week it was administered. Descriptive analysis of the data showed that no students exhibited a negative attitude towards computers, and most were fairly positive in their attitudes. The data from the survey is summarized in Appendix F. Recognizing this limitation, the following information is presented.

Hypothesis 8.1: There was no statistically significant relationship between the average communication score of the student and his or her comfort level and attitude about computers.

Test: Pearson's correlation returned a value of .60039, with a p-value of .051. Therefore, the hypothesis is not rejected at  $\alpha = .05$ .

Result: There was no statistically significant relationship between the average communication score of the student and his or her comfort level and attitude about computers.

Hypothesis 8.2: There was no statistically significant relationship between the number of scored messages for each student and his or her comfort level and attitude about computers.

Test: Pearson's correlation returned a value of .596652, with a p-value of .053.

Therefore, the hypothesis is not rejected at  $\alpha = .05$ .

Result: There was no statistically significant relationship between the number of scored messages for each student and his or her comfort level and attitude about computers.

Hypothesis 8.3: There was no statistically significant relationship between the total number of high level messages for each student and his or her comfort level and attitude about computers.

Test: Pearson's correlation returned a value of .57999, with a p-value of .061.

Therefore, the hypothesis is not rejected at  $\alpha = .05$ .

Result: There was no statistically significant relationship between the total number of high level messages for each student and his or her comfort level and attitude about computers.

Hypothesis 9.1: There was no statistically significant relationship between individual achievement on the final test for each student and his or her comfort and attitude about computers.

Test: Pearson's correlation returned a value of -.3196, with a p-value of .338.

Therefore, hypothesis 9.1 is not rejected at  $\alpha = .05$ .

Result: There was no statistically significant relationship between individual achievement on the final test for each student and his or her comfort and attitude about computers.

Hypothesis 9.2: There was no statistically significant relationship between individual achievement on the test average for each student and his or her comfort and attitude about computers.

Test: Pearson's correlation returned a value of  $-.27681$ , with a p-value of  $.41$ .

Therefore, hypothesis 9.2 is not rejected at  $\alpha = .05$

Result: There was no statistically significant relationship between individual achievement on the final test for each student and his or her comfort and attitude about computers.

### Attitudes Towards Course

In the original proposal for this study, the experimental design called for a survey to be administered to the students at the end of the course to measure their attitudes about the course and the unique way it was offered. This survey was administered before the final test; however, the survey was never re-administered to the students to allow for the instrument to be checked as reliable. Also, due to the way the survey was administered to the off campus students, one student chose not to participate. The validity of the instrument was established through expert validity on the part of two professors familiar with the course and its content. The survey can be found in Appendix A. This survey was to be done for descriptive statistical purposes only, with no pertinent hypotheses generated from its use. It should be noted that the survey was given based on a 5-point scale, with "strongly agree" worth five points, "agree" worth four points, "neutral" worth three points, "disagree" worth 2 points, and "strongly disagree" worth one point. Table 22 on the next page presents the mean score generated from each question.

Table 22. Mean score from each question

| Part 1:<br>Question Number | Mean Score | Part 2:<br>Question Number | Mean Score |
|----------------------------|------------|----------------------------|------------|
| 1                          | 4.06       | 1                          | 4.12       |
| 2                          | 4.12       | 2                          | 3.71       |
| 3                          | 4.53       | 3                          | 4.24       |
| 4                          | 2.88       | 4                          | 3.71       |
| 5                          | 3.35       | 5                          | 3.71       |
| 6                          | 2.81       | 6                          | 3.71       |
| 7                          | 3.76       | 7                          | 2.94       |
| 8                          | 3.76       | 8                          | 4.59       |
| 9                          | 2.56       | 9                          | 3.75       |
| 10                         | 1.41       | 10                         | 3.82       |
| 11                         | 3.18       | 11                         | 3.82       |
| 12                         | 4.35       | 12                         | 3.24       |

Analysis: There are several interesting items to discuss. In part 1, question #2 "I felt more involved in taking an active part in the class" scored relatively well, with most students agreeing with that statement. Question 4 "Doing the work on-line made it more difficult" scored between neutral and slightly disagree from the 17 students who responded to the survey, indicating that for the most part, they did not find the work any more difficult than regular face to face classes. The responses to Question 5 indicate that students would agree slightly with the idea that if they became bogged down with other work, they would tend to stop participating in the on-line discussion; this can be seen in the data analysis for hypothesis 5. Of particular interest are questions 7 and 8. While agreeing that use of MSUlink made it easier for them to communicate with the professor and other students, they also felt (by the exact same score) that they would have taken more of a role in group discussion had the groups met face to face. These seem to be contradictory in nature. Question 10 "I would NOT take another course that has an on-

line component" was met with strong disagreement. This indicates that the students were not negatively affected by working on-line.

For the questions from part 2, each sentence began with the phrase "The use of the technology associated with MSUlink allowed for:". All these questions, worded to reflect positively on the use of the technology, scored higher than neutral except for question 7. This question involved the turnaround time that it would take an instructor to answer questions that the students had posed. Although it was close to neutral, scoring a 2.94, it is still relevant in light of the relative scores of the other questions. The students believed that this was a problem, when compared to other classes.

Some of the questions that elicited an overall positive response should be mentioned in detail. The responses to questions 4 and 5 indicated that the students felt they were able to communicate more frequently with other students in the class, and their instructor. The responses to questions 9 and 10 indicated that the students believed they were able to work faster and more efficiently within a group format. And the response to question 12 showed that the students felt (slightly) that the group work performed in this class was more educationally rewarding when compared to face-to-face classes.

Table 23 on the next page indicates the student's average score from the survey. Questions 4, 5, 8, 9, and 10, which were posed negatively, were reversed in their scoring for this table. This would allow the results below to indicate that the higher the mean score, the more positively that student felt about the class.

Table 23. Results from survey of student's attitudes about the course.

| Student | Mean Score | Student  | Mean Score |
|---------|------------|----------|------------|
| Red 1   | 3.83       | Green 1  | 3.42       |
| Red 2   | 3.83       | Green 2  | 4.04       |
| Red 3   | 3.46       | Green 3  | 3.75       |
| Red 4   | 4.21       | Green 4  | 2.83       |
| Blue 1  | 3.92       | Yellow 1 | 3.46       |
| Blue 2  | 3.63       | Yellow 2 | 3.71       |
| Blue 3  | 3.08       | Yellow 3 | 3.63       |
| Blue 4  | 3.29       | Yellow 4 | No Score   |
| Blue 5  | 4.58       | Yellow 5 | 3.38       |

Analysis: Only one student had a negative or slightly negative overall attitude towards the use of the technology in the course: Green 4. It is interesting to note that the group means (3.83 for the Red group, 3.7 for the Blue Group, 3.51 for the Green Group, and 3.54 for the Yellow Group) were roughly the same, despite differences in the use of the technology. It is also interesting to note that the person who had the highest positive attitude towards the use of the technology, Blue 5, also had the highest average communication phase level (average communication phase levels for individuals can be found in Appendix F).

### Summary

After the testing of all hypotheses, the following results were deemed to be significant. The number of messages sent at certain phase levels was dependent upon whether the students were on campus students or off campus students, as was the number of messages sent at certain phase levels dependent upon group membership. Two significant relationships were found when comparing individual achievement data to communication variables. There was a significant relationship between an individual's

average test score and an individual's average communication score. There was also a significant relationship between an individual's average test score and the percentage of high level messages for each individual. Both relationships were inverse relationships; the lower an individual's communication score or percentage of higher level messages, the higher the average test score.

There were three hypotheses with significant findings when testing the group communication variables and group achievement variables. There was a significant relationship between the rank of each group task and the number of scored messages for each group on each task. There was also a significant relationship between the rank of each group task and the number of high level messages by each group for each task. And, there was a significant relationship between the rank of each group task and the highest level message attained by each group for that task. All were positive relationships; in general, the higher the score on the communication variable tested (whether it was the number of messages, the number of high level messages, or the highest level message attained) by each group for a task, the higher the rank of that task.

Two groups were found by trend analysis to show significant decreases in average communication score over the length of the semester. There was no significant difference in the communication of males and females, although a significant difference between males and females did exist on the final test scores.

## CHAPTER 4

### CONCLUSIONS

#### Introduction

The purpose of this study, the sample chosen, the experimental procedures used, and the results obtained are briefly reviewed in this chapter. The conclusions reached are then discussed. Some discussions concerning observations made by the researcher follows the conclusions. Finally, recommendation for further action and study are presented.

#### Summary of the Study

The purpose of this study was to determine if students participating in on-line problem-solving activities communicate differently depending upon location of the student (on campus or off campus) and whether differences in communication are related to differences in achievement. The setting for the study was Montana State University, Bozeman, Montana. The study took place during the Spring Semester of 1999, and involved a total of eighteen students.

Fourteen of the eighteen students were enrolled in Math 329, the undergraduate Modern Geometry course. Four of the students were enrolled in Math 527, a graduate level Geometry for Teachers course. The content for the courses was identical, and can be found in Appendix C.

The course was not taught in a traditional lecture setting; instead, the course materials (with the exception of textbooks) were delivered to students via the Internet through the use of the World Wide Web. Although enrollment in the course was open to any student who met the prerequisites, most of the students were secondary mathematics teachers or undergraduate students majoring in secondary mathematics education.

All four of the students enrolled in the graduate level version of the course (Math 527), and one student enrolled in the undergraduate level version of the course (Math 329) enrolled in the course as distance education students. The other thirteen students enrolled in the undergraduate level version of the course (Math 329) took the course on campus at Montana State University.

The eighteen students were placed into four collaborative work groups consisting of four or five students each. The five distance students made up one group. The other three groups were made from the thirteen on-campus students. The members of these three groups were balanced by matching on prior mathematical ability, with gender as a secondary matching variable. Prior mathematical ability was determined by the student's college grade point average in all mathematics courses that count towards earning a degree in secondary mathematics.

Each week for eleven weeks, groups were assigned a problem-solving task. The weekly group tasks were to be addressed collaboratively, with each student contributing ideas, responding to ideas, proposing strategies and procedures, demonstrating solutions, and summarizing and reporting their groups' findings, all on line. A complete record of the deliberations of each group was recorded in electronic form using the messaging and

chat tools found on MSUlink available with the First Class Client software. Substantive contributions to these deliberations that took place in face-to-face or phone conversations were to be referenced and reiterated in the electronic communications of the group.

Group problem-solving tasks were posted Monday mornings. Students had until Sunday evenings at 5:00 Mountain Time to complete each task. Assessments of the activities were based on the same criteria for each group, not depending upon which of the two communication environments were used to complete the activity, or how often the communication environments were used. All members of each group received the same grade on each task.

Each message sent by all individuals within their problem-solving groups was analyzed and ranked according to the Interaction Analysis Model developed by Gunawardena, Lowe, and Anderson (1997). These rankings were used to generate an average message score per task for each individual and each group; the total number of messages per task for each individual and each group; the total number of high level messages (defined as the number of messages scored with a phase level of 3, 4, or 5) per task for each individual and each group; the percentage of high level messages per task for each individual; and the highest phase level attained by each group per task.

Academic achievement data for individual students was gathered in the form of their midterm and final examination scores. Academic achievement data for groups was gathered in the form of the raw scores earned on their relative rankings per task. The criteria used to rank the group tasks can be found in Appendix D. Data on the student's

attitudes towards computers were gathered using the Computer Attitude Scale, developed by Loyd and Gressard (1984a).

The data were analyzed using three different statistical software packages; Microsoft Excel, Minitab, and SPSS. Use was made of the following procedures: analysis of variance, Pearson correlations, trend analysis, and Chi-square tests of independence.

The null hypotheses that the communication phase levels were independent of whether the students were on campus or off campus, or that the communication phase levels were independent of group membership were rejected.

The correlations between individual achievement and communication within the problem-solving groups were nonsignificant, except for two that showed a negative correlation. The correlations that were found showed a significant (negative) relationship between an individual's average test score and an individual's average communication score, and a significant (negative) relationship between an individual's average test score and the percentage of high level messages for each individual. The correlations between group achievement and communication within the problem-solving groups were mostly nonsignificant. However, three showed a positive correlation. Those three found a significant (positive) relationship between the rank of each group task and the number of scored messages for each group on each task, a significant (positive) relationship between the rank of each group task and the number of high level messages by each group for each task, and a significant (positive) relationship between the rank of each group task and the highest level message attained by each group for that task.

Trend analysis and descriptive analysis found that communication phase levels decreased for three of the eighteen individuals, and for two of the four groups.

No gender differences were found among the communication variables. No gender difference was found in average test score, but there was a significant difference in the final test scores between males and females.

### **Conclusions and Implications**

The researcher reached the following conclusions based on an analysis of the data collected in this study.

The level of communication employed by students was related to whether the students were on campus or off campus (Hypothesis 1.1). By examining the data, it appears that the largest discrepancy between the predicted number of communications and the actual number of communications occurs in phase one messages. The off campus students had far more communications at this level than expected, while the on campus students had less communications at this level than expected. This difference could be a result of what constitutes a phase one message. A phase one message, described by Gunawardena, Lowe, and Anderson (1997), is a message that involves the sharing or comparing of information. It is theorized by the researcher that this type of communication could be more readily accomplished by other means than on-line communication for those students who were on campus. The off campus students did not have this as an option; subsequently, they would have a higher number of phase one messages than predicted by a chi-square test.

Another interesting finding in this data is the frequency with which communications at certain phase levels occurred in this course. In one of the studies by Gunawardena, Lowe, and Anderson (1997), the phase level that occurred most often was phase 1, followed by phase 2. Phases three, four, and five occurred less frequently than the two previous phases, and all had about the same number of messages. The pilot study by this researcher using communication data from the summer geometry course found a similar scenario. This led the researcher to believe there would be a fairly direct relationship between the phase levels and the number of communications that occurred at that level. Most messages would be scored as phase one; the second most frequent phase would be phase two, and so on. However, this finding was not replicated in this study. While the largest group of messages were phase one messages, the second largest group for all on and off campus groups was phase three messages, not phase two. The margin of this difference is sufficiently large enough to merit further analysis.

An explanation for this discrepancy may lie in the nature of mathematical discourse. Phase two messages are those that involve the discovery and exploration of dissonance or inconsistency among ideas, concepts, or statements. Phase three messages are those that involve the negotiation of meaning or the construction or co-construction of knowledge. This researcher believes that for mathematicians, dissonance often occurs internally. In other words, persons engaged in meaningful mathematical problem solving will often experience, and attempt to resolve dissonance privately. Once they believe they have resolved that dissonance and have arrived at a (perceived) solution to the problem, they will then share that with the members of their respective group. In other

words, the lack of phase two communications, and/or the overabundance of phase three communications could be due to the fact that the process that is described in phase two - dissonance - occurs internally, while the attempt to construct new knowledge will occur with the other members of the group.

There was no significant relationship between the group communication variables (number of messages, average message score, number of high level messages, and highest level attained by each group for each task) and the score attained by each group on the problem-solving tasks. This result could be attributed to the lack of variability of scores on the group tasks.

When the group tasks were ranked according to the criteria in Appendix D, significant relationships were found between the total number of messages and the rankings of the group tasks, the total number of high level messages and the ranking of the group tasks, and the highest phase level attained by a group during a task and the ranking of the group tasks. This indicates that the more frequently communication occurs between group members (and the more that communication occurs at a higher level), the better these groups did at creating and writing solutions to the problem-solving tasks. This finding would agree with the findings of others (Mevarich, Sibler, and Fine, 1991) that interaction between students was the key to students learning in groups while using the computer. This would also support the idea of Schutte (1996) that students do better in WWW-based courses when they work and interact in groups. In this study, however, the interaction was not face to face; it was at a distance.

There were two significant findings when comparing individual achievement and on-line communication. There was a significant inverse relationship between an individual's average communication score and his or her average test score. There was also a significant inverse relationship between an individual's percentage of high level messages sent (this is the ratio of high level messages divided by the total messages) and his or her average test score. When testing the other six hypotheses related to individual achievement and communication, no relationships were found.

These results were somewhat surprising, given the previous findings on the group data. A Pearson's product moment correlation test was conducted to see if there existed a significant relationship between the average test score for each individual and the mathematics grade point average of the individual. Another Pearson's  $r$  was conducted testing for a significant relationship between the final test score for each individual and the mathematics grade point average of the individual. These tests were conducted since it was by mathematics grade point average that the groups were formed. These tests were conducted on only the on-campus students ( $n=13$ ), since the off-campus students were one complete group, and not formed by heterogeneous matching on mathematics grade point average.

The results of the Pearson tests found no significant relationships between the individual achievement variables and mathematics grade point average. The correlation values were .32663 for test average vs. mathematics grade point average, and .198098 for final test score vs. mathematics grade point average. The  $p$ -values were .276 and .516,

respectively. Therefore, there was no significant relationship between either the test average or final test score, and the mathematics grade point average of each student.

It is sometimes the case that a relationship between two variables does not imply causality; i.e., the independent variable influencing the dependent variable. It is believed that this might be the situation with these variables, since the communication occurred while the students worked on group tasks, while the tests were individual activities. The Pearson's correlation tests seem to support this idea. In any case, the benefit of group communication positively influencing the group academic activities did not translate to the individual level when comparing each individual's communication (in the group setting) and individual academic activities.

There could be other reasons for this surprising result. Due to the fact that since the number of students in this study was low relative to the number of hypotheses tested, a Type I error (rejecting a true null hypothesis) could have occurred in these instances. Another reason could be that while some students are very verbose and excellent communicators (and thus will communicate at high levels), they also can be relatively poor test takers, and vice versa.

The nature or structure of groups may also partially explain these findings. For example, mathematically weaker students may be able to benefit from mathematically stronger students in their group in a way that does not transfer to individual activity. They benefit during the group work from having the stronger students help solve the problems they cannot; and when they communicate about the problem, knowledge is gained, or the information is understood; thus the communication is at a high level.

Unfortunately, this knowledge is short-lived; and when the tests are given the mathematically weaker students cannot recall completely or at all how to solve that problem.

A somewhat different situation could occur as well. Some students may be high achievers as individuals but do not work well, or especially communicate well, during group activities. These individuals would do well on the individual academic tests, but would have communicated sparingly and/or at low levels during the group activities, thus helping to create a negative correlation between individual achievement and group communication. Therefore, to help establish the link between individual achievement and on-line communication within a group setting, it is recommended that either the information tested align closely with the group work, or some type of test be conducted to measure the amount of work each student does within his or her group. Thus, an individual such as that would not communicate very often or at very high levels during the group work, preferring to keep their thoughts to themselves.

Total messages per task decreased during the semester. This may have been caused by several factors. For the Red Group, the decrease to almost no on-line communication indicates that they found the method unsatisfactory in helping solve the group tasks and used other methods, despite being instructed to the contrary. This would reflect the findings of other studies (McHenry and Bozik, 1993; Smith and McNelis, 1995) that found some students located on campus to have negative feelings towards the use of technology. This does not explain why the other groups, particularly the off campus Yellow Group, had the same decrease. Perhaps their decrease lies in the

Hawthorne effect; as they became accustomed to using on-line communication, the novelty wore off. Given the ages and maturity level of the participants, this seems unlikely to account for a major part of the decrease. A more likely possibility was that as the members of each group became familiar with each other, the roles became better defined, and certain procedural aspects of what needed to be done and communicated to other members at the beginning of the semester was no longer necessary as the semester progressed.

The four groups seemed to establish a pattern of use of the on-line communication tools after the first few tasks. The Red Group deemed the use unnecessary or impractical, and for all intents and purposes, stopped using it. The Green Group used the on-line communication tools sparingly, but the communication (particularly towards the end of the semester) was almost exclusively high level communication. The Blue Group's use of on line communication was similar to the Green Groups, except their numbers of messages were higher. Perhaps the difference in number of members (five in the Blue Group, four in the Green Group) would partially account for this. The Blue Group also seemed to establish a group leader earlier in the semester than the Green Group (as observed by the researcher), which may also account for the higher number of messages. The Yellow Group used the communication tools for all communication, no matter how detailed. This group worked more cooperatively than the others; i.e., there did not seem to be one person taking charge and being the leader every week. Rather, they took turns leading the activity.

Two groups (Red and Yellow) significantly changed (decreased) average communication phase levels during the semester; the other two groups showed an increase, although not significant. The Red group decreased due to reasons mentioned earlier; the lack of use. Why the Yellow group decreased in average message score is not known. However, it is speculated that this entirely-off campus group may have been working at a very high level at the beginning of the course due to the constraint of not being able to communicate face to face. They may have been overcompensating for this by putting forth an extra effort in order to succeed and/or impress the other group members. After the first few weeks, the group may have settled into a pattern that held for the rest of the semester. In a sense, after the first few weeks, they regressed to the mean. It would be interesting to see how their average communication phase level score would be affected if the course or study continued for another semester.

Most individuals did not change communication phase levels over time. Only three of the eighteen students (Red 2, Yellow 1, and Yellow 4) were judged to show a significant decrease in communication phase level during the semester. This in turn may have heavily influenced the overall decrease of their respective groups. With the Red Group, it is debatable whether one member significantly decreasing caused the entire group to significantly decrease, since each member decreased over time. Recall that due to the lack of messages sent by these other three members, it was impossible to judge with any certainty if they did change average communication phase level. This is not the case of the Yellow Group. The other three members of the group either stayed the same or showed a slight (though nonsignificant) increase in average message score. So,

it is judged with a fair amount of confidence that the two members of the Yellow Group who showed a significant decrease in average message score influenced the group to have a significant decrease in average message score.

There is no difference in the communication of males and females when communicating on line while working in problem-solving groups. This would agree with the findings of earlier studies on computer use (Gressard and Loyd, 1987; Hayek and Stephens, 1989; Dyck and Smither, 1994); that showed there existed no significant differences between the sexes relative to communication.

### **Discussion and Observations**

When this study was originally proposed, the researcher wished to compare the relative effectiveness of the two communication mediums used in computer-mediated conferencing, the bulletin board and the chat room. To best accomplish this, the researcher decided that each group would work in one communication environment or the other when working on a group task, but not both. If using one environment for that task, they could not use the other under any circumstances. After completing a few tasks in one communication environment, the groups would change to the other environment. For example, if the groups worked using the bulletin board for their communication during weeks one through three, they would switch and use the chat room for weeks four through six. This pattern was to continue throughout the course.

This idea, while appearing feasible in theory, turned out to be impossible in practice. The four groups essentially balked at the idea, but for different reasons. The

on-campus students did not like using the chat room, since it required them to all be on a computer somewhere (usually on campus) at the same time. They much preferred the bulletin board, with the advantages of convenience in use and of not having time restrictions, as pointed out by Harasim (1990) and McComb (1993). Also, one of the advantages found using First Class Client, that of being able to attach work done in other software programs to a bulletin board message, was lost when restricting students to just the chat feature.

The off-campus students had the latter reason for not wanting to give up bulletin board postings. However, they also did not want to lose the ability to use the chat room. Due to the very nature of their group (being completely isolated from each other), they believed they could not survive as a group without the use of the chat feature. It was essential to the conducting of their work in a timely manner, since it allowed all members to communicate at the same time about the problem-solving task. The chat room allowed them to discuss what they had discovered since their last chat, put forth ideas and possible solutions for immediate feedback, set up a division of labor for the tasks, establish future timelines for completion of certain activities, etc. In short, they believed the chat feature was essential to their being a group, and not just a collection of individuals working on a project. Too them, the chat room helped establish the community of the group in ways that bulletin board postings alone could not do, or at least not do as effectively.

For these reasons, the idea of allowing students to use only one communication medium or the other was abandoned. While a comparison of the two major on-line

communication methods may have been informative and useful in future course design, much knowledge was gained from how the students reacted to such a proposal. It informed both the instructor of the course and the researcher that limiting the ability of students to communicate on-line could seriously hinder the academic achievement of the students. This could be likened (from a student perspective) as the same as allowing students in the classroom to see or hear during class time, but not both. It is also highly probable that the students would not have felt as positive towards the course and the technology use in the course as well.

One of the factors among the groups that seemed to result in a larger amount of communication and higher phase levels in that communication was the emergence of a group leader. A leader emerged for all groups except one, the Red Group. Perhaps not coincidentally, this group also had the lowest output in terms of messages, and their average communication phase level score rarely passed the lowest phase level after a few weeks of the semester had gone by. In the other three groups, however, there was one clear leader, even if other members of these groups were designated weekly leaders of the problem-solving task.

These leaders seemed to consistently be at or near the top of their group in number of messages and/or average message score week after week. They were the people that helped set the agenda for working on and solving the task for that week, and were the people that the other members of the group looked to when the work met a roadblock. Interestingly, it was not always the case that the leader of a group was the person who had the highest mathematics grade point average.

The Blue Group seemed to establish a leader first, about 3 to 4 weeks into the study. The Green Group did not seem to establish a leader until about mid-semester. The Yellow Group, interestingly enough, seemed to have two leaders. One member seemed to be the established leader early in the semester, from the very first task. About mid-semester this changed, and a different person emerged as the leader. Of interest is the fact that this second leader did not join the class until after the first task was completed. Perhaps because of the late start, he or she did not feel comfortable in becoming the group leader until after some time had passed, and had established some intimacy with the group and its members.

In any case, it was observed that if a group did have an established leader, their communication on-line as a group seemed to be more focused on solving the problem, and that person would communicate more often and at a higher level than his or her peers in the group. It would seem that establishing a group leader is essential for a group to perform at the peak of its ability.

Another interesting observation was the effect that the instructor had on the chat room discussions. When groups participated in a chat room discussion without the instructor present, the chats for the most part did not accomplish much meaningful mathematics and took place at low communication phase levels. An occasional exception to this occurred when a group member took charge of the chat, and in effect became the group leader for that discussion. It was more often than not the case that the leader of this chat would be the leader discussed above.

When the instructor was present, the conversations in the chat room were more interesting, more in-depth, at a higher phase level, and much more verbose on the part of the students. One obvious reason for this is that the instructor knows the answer to the problem-solving task, and can much more easily guide the students down the correct path than they can by guiding themselves. It is obvious that in the classroom setting where an instructor is much more knowledgeable about the subject matter than the students, the students rely on the instructor for guidance. The same is true in a distance learning setting. The reliance may be even more important, since a student taking a course at a distance does not usually have the luxury of asking another authority for guidance. This could be the reason why students viewed the turnaround time it took the professor in this class to answer questions via MSUlink in a slightly negative light, when all other factors of MSUlink and First Class Client were viewed positively. The student placed a high emphasis on communication with the professor.

### **Recommendations for Further Action**

Based upon the findings of this study, the researcher recommends that the Department of Mathematical Sciences of Montana State University take the following action:

1. Instructors of distance learning courses should set up classes to maximize communication between students, especially in problem-solving groups. Based on the findings of this study, amount of communication and level of communication are necessary for problem-solving groups to maximize their potential in designing a

quality solution. Therefore, instructors of distance learning courses should make the methods of communication among their students, and between the students and instructor, a high priority. The product chosen to facilitate the communication should be dependable, reliable, and easy to use. The students should be given ample opportunity to learn how to use the communication tools at their maximum potential. And, all students should be encouraged to communicate with other members of their group (or class) using both the bulletin board and chat room facilities.

2. Instructors must be available to communicate with the students on-line as often as possible, possibly through set on-line "office hours". On the survey given to the students at the end of the course, the only question about the use of MSUlink to generate negative feedback was the question "the use of the technology associated with MSUlink allowed for quicker turnaround time on questions to the instructor". The response was only slightly negative; however, given the fact that all other questions generated positive responses, it would seem to indicate that students place a high priority on instructor feedback. Therefore, in the instructor's syllabus, on-line office hours could be established and mentioned. This would be the time or times during the week when the instructor (or an assistant) would be available to conduct a chat session. However, it could be equally effective if the instructor stated that this would be the time or times during the week that he or she would specifically answer bulletin board questions. Students could then expect an answer during or shortly after this time to their inquiries. Perhaps it would be best if a combination of the two was used,

but that would depend heavily on the instructor's time available, and/or if the instructor had others who could assist in this chore.

### **Recommendations for Further Study**

The researcher recommends the following additional research:

1. A similar study should be done in a subject area besides mathematics, or a topic area other than college geometry. As stated by Gunawardena, Lowe and Anderson (1997) "Further work with the model and instrument, especially with formal credit courses and online work teams, is both needed and ongoing."
2. A study should be conducted extending the length of time to go beyond a semester, to include a second or perhaps a third semester. This study could check to see if the trends in communication of groups and individuals that were discovered in this study would continue or change in some fashion.
3. Since there was only one off campus group for this study, a study conducted having more than one off campus group would be advised. This study could better define if off campus groups have different communication patterns than their on-campus counterparts.
4. Similarly, if the situation of this study is repeated - that of having a small number of off campus students when compared to the on campus students - a study should be conducted that would use problem-solving groups that contain both on and off campus students.

5. A study should be conducted that accounts for the difference in numbers of each group, i.e., normalizing group membership.
6. A study should be conducted that would check the communication phase level of individuals vs. relative experience using computers, and check the communication phase level of individuals vs. a test or measure that would determine the overall communication ability of the individuals prior to the individuals taking part in the study.
7. A qualitative study should be conducted on what students, not teachers as done by Soo and Bonk (1998), perceive as the benefits and drawbacks of using both synchronous and asynchronous communication in distance learning courses.
8. A study should be conducted that compares communication of students and achievement using both asynchronous and synchronous forms of communication. However, this must be designed with caution, given that too much structure or rigor imposed on the students may result in tainted data, or cause friction in the class as outlined earlier. If one method (either synchronous or asynchronous) of communication is imposed as the sole method of communication, students working in that group may find it difficult to work at the same level than if given the freedom to choose how they wish to communicate, as delineated earlier in this chapter. For example, students who are at a distance and are working collaboratively may find the use of a chat facility indispensable. On the other hand, restricting students to just the use of the chat room creates a time constraint not present when using asynchronous communication. This could make it difficult for collaborative groups to meet enough

to make meaningful progress on the problem-solving task. Therefore, the course and study would have to allow (and perhaps require) the use of both asynchronous and synchronous communication methods for each group task.

9. A study should be conducted that uses a better measure of individual achievement other than the individual tests given as part of the course. This measure should align directly with the work the students performed while working in their problem-solving groups.
10. A study should be conducted on how each member of a group perceives the contribution of other members of his/her group. This in turn could be compared to the individual achievement measure discussed in number 9, and the communication phase level of the students in the group.
11. A study should be conducted to determine the effect that "leaders" of a group have on that group's performance, both academically and in the on-line communication of that group. There are several variations on how this study could be performed. The instructor could choose a student to be the leader of the group for the entire semester, or the instructor could appoint students as leaders of the group on a week by week basis, or the instructor could make no such designations, and the study could see how each group develops a leader or leaders naturally...or do not develop a leader or leaders ... and hence compare these developments to their academic achievement and on-line communication. It was observed by the researcher, but not statistically studied or verified, that the groups that formed a leader, or designated weekly leaders, seemed to accomplish more academically and communicated more often than those

groups that did not have a leader. It was also observed, but not verified statistically, that the leader would communicate at a higher phase level during the week or weeks that he or she was the leader, and subsequently drop in communication phase level during the weeks that he or she was not the leader. A study to verify these observations would seem to be essential in determining the best manner in designing distance learning courses that involve group work.

12. A study should be conducted to determine the effect of having the instructor lead and direct the learning of the problem-solving groups, especially during chat situations. It was observed by the researcher, but not statistically studied or verified, that when the instructor was a participant in the chat situations, the communication of the other members of the group would reach higher phase levels, and more understanding would be accomplished as a result.

**REFERENCES CITED**

## References Cited

- Ayers, Thomas, Davis, George, Dubinsky, Ed, and Lewin, Philip (1988). Computer experiences in learning composition of functions. *Journal for Research in Mathematics Education*, 19(3), 246-259.
- Akbari-Zarin, Mansour, and Gray, Mary W. (1990). Computer assisted instruction and critical thinking. *Journal of Computers in Mathematics and Science Teaching*, 9(4), 71-78.
- Beaudrie, B., Slater, T., Caditz, D., and Stevenson, S. (1998) Teaching astronomy by internet jigsawing, *Learning and Leading with Technology*, 26(4), 28-34.
- Bober, Marcie (1998). Online course delivery: is meaningful evaluation possible? *Distance Education Report*, 2(11) 1-3, 7.
- Cennamo, Katherine S., Savenye, Willhelmina, C., and Smith, Patricia L. (1990). Can interactive video overcome the "couch potato" syndrome? Proceedings of Selected Paper Presentations at the Convention of the Association for Educational Communications and Technology, USA.
- Cheng, Hui-Chuan, Lehman, James, and Armstrong, Penny (1991). Comparison of performance and attitude in traditional and computer conferencing classes. *The American Journal of Distance Education*, 5(3), 51-64.
- Council for Higher Education Accreditation (CHEA), (1999). *Distance Learning in Higher Education* [Online]. Available: <http://www.chea.org/Commentary/distance-learning.html>
- Dodge, Bernie (1995). *Some Thoughts About WebQuests* [Online]. Available: [http://edweb.sdsu.edu/courses/edtec596/about\\_webquests.html](http://edweb.sdsu.edu/courses/edtec596/about_webquests.html)
- Dodge, Bernie (1997). *The Webquest Page* [Online]. Available: <http://edweb.sdsu.edu/webquest/webquest.html>.
- Dyck, Jennifer L., and Smither, Janan Al-Awar (1994). Age differences in computer anxiety: the role of computer experience, gender, and education. *Journal of Educational Computing Research*, 10(3), 239-248.
- Eddy, John Paul, and Spaulding, Donald (1996). Internet, computers, distance education, and people failure: research on technology. *Education*, 116(3), 391-392.
- Euro-Marketing Associates (1999). *Global Internet Statistics (by Language)* [Online]. Available: <http://www.euromktg.com/globstats/>

- Ferguson, George Andrew (1981). Statistical Analysis in Psychology and Education (5<sup>th</sup> Edition). New York: McGraw Hill, 1981.
- Funkhouser, Charles, and Dennis, J. Richard (1992). The effects on problem-solving software on problem-solving ability. *Journal of Research on Computing in Education*, 24(3), 338-347.
- Funkhouser, Charles (1993). The influence of problem-solving software on student attitudes about mathematics. *Journal of Research on Computing in Education*, 25(3), 339-346.
- Gressard, Clarice P., and Loyd, Brenda H. (1987). An investigation of the effects of math anxiety and sex on computer attitudes. *School Science and Mathematics*, 87(2), 125-135.
- Grimes, G. (1993). Going the distance with technology...happy 100<sup>th</sup> anniversary to distance education. *etin*, 6-8.
- Gunawardena, Charotte N., Lowe, Constance A., and Anderson, Terry (1997). Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. *Journal of Educational Computing Research*, 17(4) 397-431.
- Harasim, Linda M. (1990). Online education: an environment for collaboration and intellectual amplification. In Linda M. Harasim (Ed.), Online Education: Perspectives on a New Environment (pp. 185-213). New York, NY: Praeger Publishers.
- Hayek, Linda M., and Stephens, Larry (1989). Factors affecting computer anxiety in high school computer science students. *Journal of Computers in Mathematics and Science Teaching*, 8(4), 73-76.
- Heid, M. Kathleen (1988). Resequencing skills and concepts in applied calculus using the computer as a tool. *Journal for Research in Mathematics Education*, 19(1), 3-25.
- Henri, F. (1992). Computer conferencing and content analysis. In Kaye, A. (Ed.) Collaborative Learning through Computer Conferencing: The Najaden papers. Berlin: Springer-Verlag.
- Herther, Nancy K. (1997). Education over the web: distance learning and the information Professional. *Online*, 21(5), 63-72.
- Hiltz, Starr Roxanne (1993). Correlates of learning in a virtual classroom. *International Journal of Man Made Machines Studies*, 39, 71-78.

- Hooper, Simon (1992). Effects of peer interaction during computer-based mathematics instruction. *Journal of Educational Research*, 85(3), 180-189.
- Hornik, Robert C. (1974, April). Television, background characteristics and learning in El Salvador's educational reform. Paper presented at the American Educational Research Association Annual Meeting, Chicago, IL.
- Howe, Denis (1993). *The Free On-Line Dictionary of Computing* [Online]. Available: <http://www.instantweb.com/~foldoc/>
- Hughes, Joan E. (1997). *The Virtual Literacy School, a Hypermedia Environment: Issues of Design and Research* [Online]. Available: <http://www.educ.msu.edu/homepages/hughesjo/ideas.html>
- Judson, Phoebe T. (1990). Calculus I with computer algebra. *Journal of Computers in Mathematics and Science Teaching*, 9(3), 87-93.
- Loyd, B. H., and Gressard, C. (1984 a). Reliability and factorial validity of computer attitude scales. *Educational and Psychological Measurement*, 44(2), 501-505.
- Loyd, B.H., and Gressard, C. (1984 b). The effects of sex, age, and computer experience on computer attitudes, *AEDS Journal*, 18, 67-77.
- Loyd, B.H., and Gressard, C. (1987). An investigation of the effects of math anxiety on sex and computer attitudes. *School Science and Mathematics*, 87(2), 125-135.
- Matthews, Diane (1999). The origins of distance education and its use in the United States. *T. H. E. Journal*, 27(2), 54-68.
- Maurer, Matthew M, and Simonson, Michael R. (1984, January). Development and validation of a measure of computer anxiety. Paper presented at the Annual Meeting of the Association for Educational Communications and Technology, Dallas, TX.
- Mayes, Robert L. (1992). The effects of using software tools on mathematical problem solving in secondary schools. *School Science and Mathematics*, 92(5), 243-248.
- McComb, Mary (1993). Augmenting a group discussion course with computer-mediated communication in a small college setting. *Interpersonal Computing and Technology Journal*, 1(3), 1-16.
- McHenry, Lynnea, and Bozik, Mary (1995). Communicating at a distance: A study of interaction in a distance education classroom. *Communication Education*, 44, 362-371.

- Merisotis, Jamie P., and Phipps, Ronald A. (1999). What's the difference? Outcomes of distance vs. traditional classroom-based learning. *Change*, 31(3), 12-17.
- Mevarech, Zemira R., and Rich, Y. (1985). Effects of computer-assisted instruction on disadvantaged pupils' cognitive and affective outcomes, *Journal of Educational Research*, 79, 42-46.
- Mevarech, Zemira R., Silber, Ora, and Fine, Devorah (1991). Learning with computers in small groups: cognitive and affective outcomes. *Journal of Educational Computing Research*, 7(2), 233-243.
- National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.
- Nelson, T.H. (1967). Getting it out of our systems. In Schechter, G. (Ed.) Information Retrieval: A Critical Review Washington D.C.: Thompson Books.
- Palmiter, Jeanette R. (1991). Effects of computer algebra systems on concept and skill acquisition in calculus. *Journal for Research in Mathematics Education*, 22(2), 151-156.
- Potter, David, and Chickering, Arthur W. (1991). The 21<sup>st</sup> century university: the role of government. In Sims, Ronald R. And Sims, Serbrenia J. (Eds.) Managing Institutions of Higher Education into the 21<sup>st</sup> Century: Issues and Implications (pp. 10-30). New York, NY: Greenwood Press.
- Salomon, Gavriel (1984). Television is "easy" and print is "tough": the differential Investment of mental effort in learning as a function of perceptions and attributions. *Journal of Educational Psychology*, 76, 647-658.
- Schulman, Alan H., and Sims, Randi L. (1999). Learning in an online format versus and in-class format: an experimental study. *T. H. E. Journal*, 26(11), 54-56.
- Schutte, Jerald G. (1996). *Virtual Teaching in Higher Education: The New Intellectual Superhighway or Just Another Traffic Jam?* [Online]. Available: <http://www.csun.edu/sociology/virexp.htm>
- Seagren, Al, and Watwood, Britt (1996, February) The Virtual Classroom: Great Expectations. Delivering Graduate Education by Computer: A success story. Paper presented at the Annual International Conference of the National Community College Chair Academy, Phoenix, AZ.

- Slater, Timothy F., Beaudrie, Brian P., and Fixen, Robert L., (1998). Integrating K-12 Hypermediated Earth System Science Activities Based on World Wide Web Resources, *Journal of Geoscience Education*, 46(2), 149-153.
- Smith, Dennie L., and McNelis, Mary J. (1993, April). Distance education: graduate student attitudes and academic performance. Paper presented at the American Educational Research Association Annual Meeting, Atlanta, GA.
- Smith, J.B. (1994). Collective intelligence in computer-based collaboration. Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- Soo, Keng-Soon, and Bonk, Curt J. (1998). Interaction: What does it Mean in Online Distance Education? Paper presented at the World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications, Freiburg, Germany.
- State University of New York at Stony Brook (1998). *Internet Glossary (Brief)* [Online]. Available: <http://ccmail.sunysb.edu/library/INTGLOS.HTM>
- Swadener, Marc, and Hannafin, Michael (1987). Gender similarities and differences in sixth graders' attitudes towards computers: an exploratory study. *Educational Technology*, 27, 37-42.
- Tall, David, and Thomas, Michael (1991). Encouraging versatile thinking in algebra using the computer. *Educational Studies in Mathematics*, 22, 125-147.
- Tilidetzke, Robert (1992). A comparison of CAI and traditional instruction in a college algebra course. *Journal of Computers in Mathematics and Science Technology*, 11, 53-62.
- Velsmid, D. A. (1997). The electronic classroom. *Link-Up*, 14, 32-33.
- Walther, Joseph B., Anderson, Jeffrey F., and Park, David W. (1994). Interpersonal effects in computer-mediated interaction. *Communication Research*, 21(4), 460-487.
- Wesley, Marion T. Jr., and Franks, Melvin E. (1995, November). The Virtual Classroom, Authentic Assessment, and Learning Process Control in Online Teacher Development to Support Internet Telecommunications in Education. Paper presented at the Mid-South Educational Research Association Annual Conference, Biloxi, MS.
- West, Peter (1995). Del. To spend \$30 million to build fiber-optic network for schools. *Education Week*, 14, 13.

- West, Peter. (1996) Thousands turn out to wire Calif. Schools for the Internet. *Education Week*, 15, 8-10.
- Wileman, Stanley, Konvalina, John, and Stephens, Larry (1981). Factors influencing success in beginning computer science courses. *Journal of Educational Research*, 74(4), 223-226.
- Willis, Barry (1995). *Guide #1 Distance Education: An Overview* [Online]. Available: <http://www.uidaho.edu/evo/dist1.html>
- Woodrow, Janice E. (1991). A comparison of four computer attitude scales. *Journal of Educational Computing Research*, 7(2), 165-187.
- Yakimovicz, Ann D., and Murphy, Karen L. (1995). Constructivism and collaboration on the Internet: case study of a graduate class experience. *Computers in Education*, 24(3), 203-209.

## APPENDICES

**APPENDIX A**

**THE INSTRUMENTS**

**Interaction Analysis Model for Examining Social Construction  
of Knowledge in Computer Conferencing**  
(Gunawardena, Lowe, and Anderson, 1997)

Phase I: Sharing/Comparing of Information. Stage one operations include:

- A. A statement of observation or opinion
- B. A statement of agreement from one or more other participants
- C. Corroborating examples provided by one or more participants
- D. Asking and answering questions to clarify details of statements
- E. Definitions, description, or identification of a problem

Phase II: The Discovery and Exploration of Dissonance or Inconsistency among Ideas, Concepts, or Statements. Operations which occur at this stage include:

- A. Identifying and stating areas of disagreement
- B. Asking and answering questions to clarify the source and extent of disagreement
- C. Restating the participant's position, and possibly advancing arguments or considerations in its support by references to the participant's experience, literature, formal data collected, or proposal of relevant metaphor or analogy to illustrate point of view

Phase III: Negotiation of Meaning/Co-construction of Knowledge

- A. Negotiation or clarification of the meaning of terms
- B. Negotiation of the relative weight to be assigned to types of argument
- C. Identification of areas of agreement or overlap among conflicting concepts
- D. Proposal and negotiation of new statements embodying compromise, co-construction
- E. Proposal of integrating or accommodating metaphors or analogies

Phase IV: Testing and Modification of Proposed Synthesis or Co-construction

- A. Testing the proposed synthesis against "received fact" as shared by the participants and/or their culture
- B. Testing against existing cognitive schema
- C. Testing against personal experience
- D. Testing against formal data collected
- E. Testing against contradictory testimony in the literature

Phase V: Agreement Statement(s)/Application of Newly-Constructed Meaning

- A. Summarization of agreement(s)
- B. Applications of new knowledge
- C. Metacognitive statements by the participants illustrating their understanding that their knowledge or ways of thinking (cognitive schema) have changed as a result of the conference interaction

## SURVEY OF ATTITUDES TOWARD LEARNING ABOUT AND WORKING WITH COMPUTERS

Brenda H. Loyd and Clarice P. Gressard  
University of Virginia

*The purpose of this survey is to gather information concerning people's attitudes toward learning about and working with computers. It should take about five minutes to complete this survey. All responses are kept confidential. Please return the survey to your instructor when you are finished.*

Please check the blank which applies to you.

1. Age: ☐ 22 or less    ☐ 23-25    ☐ 26-30  
                                  ☐ 31-35    ☐ 36-40    ☐ 41-45  
                                  ☐ 46-50    ☐ 51-55    ☐ 55+
2. College level completed: ☐ 1<sup>st</sup> year    ☐ 2<sup>nd</sup> year    ☐ 3<sup>rd</sup> year    ☐ 4<sup>th</sup> year  
                                                          ☐ Bachelors    ☐ Masters    ☐ Doctorate

Major area of study: \_\_\_\_\_

4. Sex:    ☐ Male                                    ☐ Female

Experience with learning about or working with computers:

- ☐ 1 week or less                                    ☐ 1 week to 1 month    ☐ 1 month to 6 months  
☐ 6 months to 1 year                                    ☐ 1 year or more

Briefly state the type of computer experience: \_\_\_\_\_

### COMPUTER ATTITUDE SCALE

*Below are a series of statements. There are no correct answers to these statements. They are designed to permit you to indicate the extent to which you agree or disagree with the ideas expressed. Place a checkmark in the space under the label which is closest to your agreement or disagreement with the statements.*

- |                                                   | Strongly<br>Agree        | Slightly<br>Agree        | Slightly<br>Disagree     | Strongly<br>Disagree     |
|---------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1. Computers do not scare me at all.....          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. I'm no good with computers.....                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. I would like working with computers.....       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. I will use computers many ways in my life..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

- |                                                                                                                                          | Strongly<br>Agree        | Slightly<br>Agree        | Slightly<br>Disagree     | Strongly<br>Disagree     |
|------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 5. Working with a computer would make me<br>very nervous.....                                                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Generally, I would feel OK about trying a<br>new problem on the computer.....                                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. The challenge of solving problems with<br>computers does not appeal to me.....                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Learning about computers is a waste of time....                                                                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. I do not feel threatened when others talk about<br>computers.....                                                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. I don't think I would do advanced<br>computer work.....                                                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11. I think working with computers would be enjoyable<br>and stimulating.....                                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12. Learning about computers is worthwhile.....                                                                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13. I feel aggressive and hostile<br>toward computers.....                                                                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14. I am sure I could do work with computers.....                                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15. Figuring out computer problems does not appeal<br>to me.....                                                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16. I'll need a firm mastery of computers for my<br>future work.....                                                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 17. It wouldn't bother me at all to take computer<br>courses.....                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 18. I'm not the type to do well with computers.....                                                                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 19. When there is a problem with a computer run<br>that I can't immediately solve, I would stick<br>with it until I have the answer..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 20. I expect to have little use for computers<br>in my daily life.....                                                                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

- |                                                                                                                      | Strongly<br>Agree        | Slightly<br>Agree        | Slightly<br>Disagree     | Strongly<br>Disagree     |
|----------------------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 21. Computers make me feel uncomfortable.....                                                                        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 22. I am sure I could learn a computer language.....                                                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 23. I don't understand how some people can<br>spend so much time working with computers<br>and seem to enjoy it..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 24. I can't think of any way that I will use computers<br>in my career.....                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 25. I would feel at ease in a computer class.....                                                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 26. I think using a computer would be very hard<br>for me.....                                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 27. Once I start to work with the computer, I would<br>find it hard to stop.....                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 28. Knowing how to work with computers will<br>increase my job possibilities.....                                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 29. I get a sinking feeling when I think of trying<br>to use a computer.....                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 30. I could get good grades in computer courses...                                                                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 31. I will do as little work with computers as<br>possible.....                                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 32. Anything that a computer can be used for,<br>I can do just as well some other way.....                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 33. I would feel comfortable working with a<br>computer.....                                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 34. I do not think I could handle a computer<br>course.....                                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 35. If a problem is left unsolved in a computer class,<br>I would continue to think about it afterward...            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

- |                                                                                     | Strongly<br>Agree        | Slightly<br>Agree        | Slightly<br>Disagree     | Strongly<br>Disagree     |
|-------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 36. It is important to me to do well in computer<br>classes.....                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 37. Computers make me feel uneasy and<br>confused.....                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 38. I have a lot of self-confidence when it comes<br>to working with computers..... | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 39. I do not enjoy talking with others about<br>computers.....                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 40. Working with computers will not be important<br>to me in my life's work.....    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

## Student Technology Attitude Survey

### Modern Geometry Course

The purpose of this survey is to gather information concerning student's attitudes towards the use of the technology in the Math 329 (or Math 527) course. It should take about 10 minutes to complete this survey. All responses are kept confidential. Please return the survey to your instructor when you are finished.

Below are a series of statements. There are no correct answers to these statements. They are designed to permit you to indicate the extent to which you agree or disagree with the ideas expressed. Place a checkmark in the space under the label which is closest to your agreement or disagreement with the statement.

|                                                                                                                                                               | Strongly Agree | Slightly Agree | Neutral | Slightly Disagree | Strongly Disagree |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------------|---------|-------------------|-------------------|
| 1. The fact that my work could be read by other students increased my motivation to do a thorough job.                                                        |                |                |         |                   |                   |
| 2. I felt more involved in taking an active part in the class.                                                                                                |                |                |         |                   |                   |
| 3. I found the comments that other students made useful to me.                                                                                                |                |                |         |                   |                   |
| 4. Doing the work on-line made it more difficult.                                                                                                             |                |                |         |                   |                   |
| 5. When I became busy with other things, I was more likely to stop participating in the on-line work than I would be to skip a class.                         |                |                |         |                   |                   |
| 6. Working the problems on-line was more convenient.                                                                                                          |                |                |         |                   |                   |
| 7. Having the computer conferencing system (chat rooms, bulletin boards) available to me made it easier for me to "talk" to my professor and fellow students. |                |                |         |                   |                   |
| 8. I would take part in group work discussion more if the groups met face to face.                                                                            |                |                |         |                   |                   |
| 9. I didn't work as hard in group work in the on-line format as I would face to face.                                                                         |                |                |         |                   |                   |
| 10. I would NOT take another course that has an on-line component.                                                                                            |                |                |         |                   |                   |
| 11. I found the course to be a better learning experience than normal face to face courses.                                                                   |                |                |         |                   |                   |
| 12. I learned a great deal more useful information because of the technology.                                                                                 |                |                |         |                   |                   |

For each statement below, place a checkmark in the space under the label which is closest to your agreement or disagreement with the statements. Begin each sentence with the statement: "The use of the technology associated with MSUlink allowed for:"

| "The use of the technology associated with MSUlink allowed for:"                                        | Strongly Agree | Slightly Agree | Neutral | Slightly Disagree | Strongly Disagree |
|---------------------------------------------------------------------------------------------------------|----------------|----------------|---------|-------------------|-------------------|
| 1. initiation of conversations with the instructor and other students.                                  |                |                |         |                   |                   |
| 2. more detailed comments from the instructor pertaining to questions and on assignments.               |                |                |         |                   |                   |
| 3. more convenience when turning in assignments.                                                        |                |                |         |                   |                   |
| 4. more frequent communication with other students.                                                     |                |                |         |                   |                   |
| 5. more frequent communication with the instructor.                                                     |                |                |         |                   |                   |
| 6. increasing my ability to express my ideas in writing and clarifying my thoughts.                     |                |                |         |                   |                   |
| 7. quicker turnaround time on questions to the instructor.                                              |                |                |         |                   |                   |
| 8. the ability to edit pieces of assignments together more easily.                                      |                |                |         |                   |                   |
| 9. the ability to work faster within a group format.                                                    |                |                |         |                   |                   |
| 10. the ability to work more efficiently within a group format.                                         |                |                |         |                   |                   |
| 11. an increase in the quality of my education in this class.                                           |                |                |         |                   |                   |
| 12. more educationally rewarding group work in this class, when compared to other face to face classes. |                |                |         |                   |                   |

Answer the questions on the following page.

Please check the blank which applies to you:

1) age:

☐ 22 or less    ☐ 23-25    ☐ 26-30    ☐ 31-35  
☐ 36-40    ☐ 41-45    ☐ 46-50    ☐ 50 +

2) College level completed:

☐ 1<sup>st</sup> year    ☐ 2<sup>nd</sup> year    ☐ 3<sup>rd</sup> year    ☐ 4<sup>th</sup> year  
☐ Bachelors    ☐ Masters    ☐ Doctorate

3) Major Area of Study: \_\_\_\_\_

4) Sex: ☐ Male    ☐ Female

Experience with learning about or working with computers before this course:

☐ less than 6 months    ☐ 6 months to 1 year  
☐ 1 to 2 years    ☐ greater than 2 years

**APPENDIX B**

**THE GROUP TASKS**

## PRELIMINARIES

Greetings,

Please read and follow the instructions carefully. If you have questions, feel free to contact me at work or at home.

Dave Thomas

Office Phone 406 994-5431

Office FAX 406 994-1789

Home phone 406 582-9480

## GROUP MEMBERSHIP

You have been assigned to one of the following groups. Each group consists of 4-5 students and has its own conference within the Math 527/Geometry Spring 1999/Transformation Geometry conference. For fairness, an effort has been made to equalize the groups based on past success in university mathematics classes.

Red Group -

Blue Group - <Individuals names withheld>

Green Group -

Yellow Group -

## WEEKLY ROUTINE

Every Monday morning, a group task will be posted. Begin work immediately, focusing concepts and procedures encountered in the readings, exercises, and laboratory activities on the task. Regardless of how ideas are explored, they must be recorded in the MSUlink group conference. Furthermore, the record must reflect the interplay of ideas and individuals in the group. A summary of the group's findings is not enough. On Thursday or Friday, each group will meet/conference with the instructor for 25 minutes to review progress, ask questions, deal with technical issues, and discuss the format for the group report.

## GROUP REPORT

By 5pm the following Sunday, one member of the group must submit a comprehensive solution to the assigned task. The solution must take the form of an electronic report submitted via MSUlink as a private message to Dave Thomas. The message should include the following elements:

- Problem Statement
- Key Mathematical Concepts
- Strategic Plan and/or Approach
- Use of Technology
- Principal Finding or Result
- Necessary Graphics and/or Other Files
- Discussion and/or Explanation

**GROUP COMMUNICATIONS**

Each group member must contribute ideas, respond to ideas, propose strategies and/or procedures, demonstrate solutions, summarize and report findings, and participate in the writing of the group report. Substantive information incorporated in MSUlink chats must be copied and pasted into the group's messages. Substantive contributions that take place in face-to-face or phone conversations must be referenced and reiterated in the messaging system. Having said that, students are encouraged to meet, talk on the phone, use the chat facility, and otherwise take full advantage of opportunities to discuss course content. It is OK to read messages in other groups. Never post a message to another group. If you incorporate something from another group in your group discussions, give credit.

**GROUP TASK #1**

The class notes posted in PDF format above provide matrix methods for performing translations and rotations about the origin. Your task is to develop a matrix method for performing rotations about points other than the origin. Your method must use a composition of translation(s) and rotation(s) about the origin. In presenting your method, include at least one computer graphic illustrating your approach. Explain the underlying mathematics thoroughly.

**GROUP TASK #2**

Under an unknown linear transformation  $T$ , the point set

$$\begin{bmatrix} 0 & -1 & -3 \\ 0 & -1 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

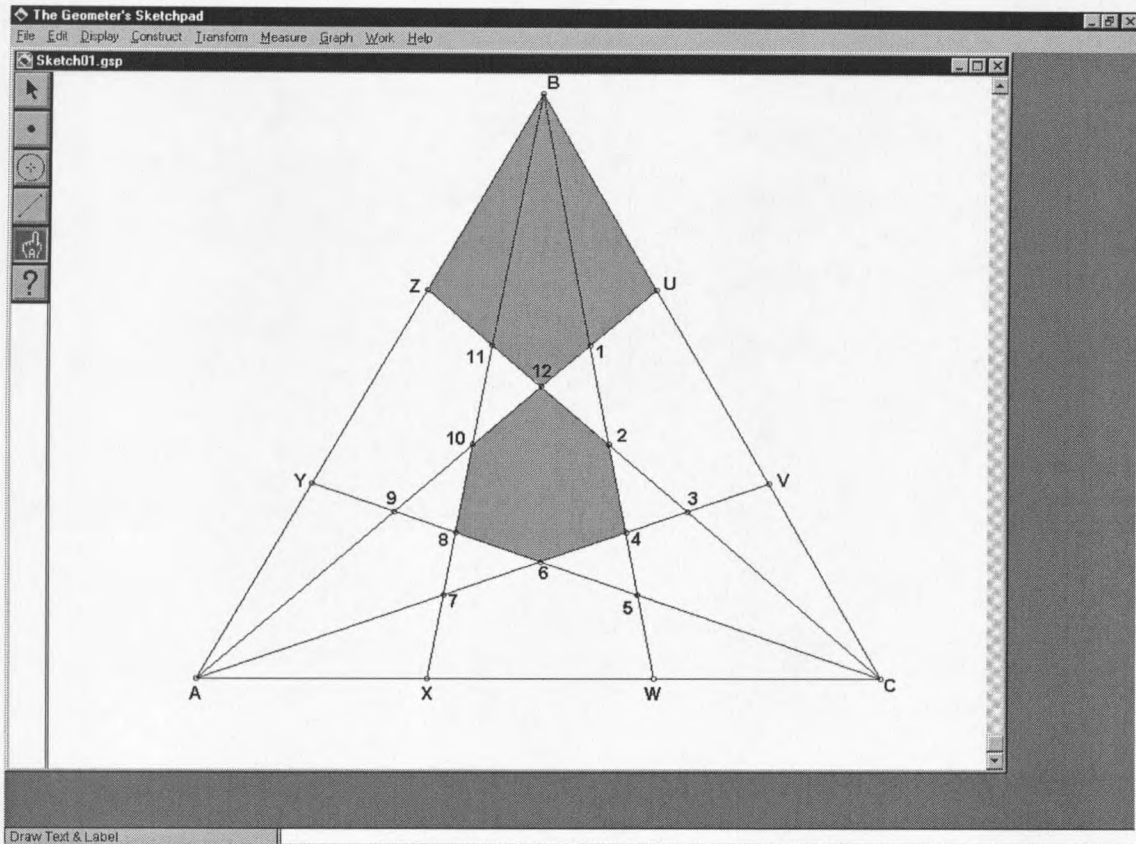
is mapped onto the point set

$$\begin{bmatrix} \sqrt{3} & \frac{3\sqrt{3}}{2} + \frac{1}{2} & \sqrt{3} + \frac{3}{2} \\ 1 & \frac{\sqrt{3}}{2} + \frac{1}{2} & \frac{3\sqrt{3}}{2} + 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Find a  $3 \times 3$  transformation matrix for  $T$  and identify all points and lines that are invariant under the transformation. Give a geometric description of the transformation. Attach an Animate movie that demonstrates the transformation.

The updated class notes in PDF format in the Transformation Geometry conference discuss geometric and matrix methods for identifying invariant points and lines associated with various linear transformations.

## GROUP TASK #3



The figure above is attached to this MSUlink message as gt3.gsp, a Geometers Sketchpad file. It was constructed by creating a triangle, intersecting its sides, connecting the trisection points to the opposite vertices. A few polygons are shaded to suggest shapes worth investigating. Do not limit your investigation to the polygons already shaded. Discover everything you can about the relationships between the segments, angles, and areas. State a formal conjecture for each discovery. Prove at least one of your discoveries.

**GROUP TASK #4**

1. Use your web browser to open the URL  
<http://www.geom.umn.edu/~demo5337/Group2/welcome.html>
2. "An Exploration of the Concurrency Points in a Triangle" has three parts:
  - Triangle Investigations
  - Euler Line
  - Nine Point Circle

Work through all three parts, studying both the content and the manner in which it is presented.

3. Using analytic geometry and as much matrix notation as you can employ, show that the nine-point circle and the circumcircle are related by a linear transformation, a dilation using the orthocenter as the center of the dilation and a scaling factor of  $1/2$ . The transformation matrix for a dilation with center  $(c_1, c_2, 1)$  and ratio  $r$  is

$$\begin{bmatrix} r & 0 & c_1(1-r) \\ 0 & r & c_2(1-r) \\ 0 & 0 & 1 \end{bmatrix}$$

## GROUP TASK #5

You have been using the Geometer's Sketchpad to discover and test relationships between segments, angles, and areas. The general strategy employed in the search for relationships is to construct the figure in question, measure its features, compare measurements, then observe which features, measurements, or comparisons remain invariant when the figure is dynamically transformed. Once a relationship has been discovered and formulated as a conjecture, it may be tested or demonstrated informally using the Sketchpad using the same strategy.

The NCTM Standards 2000 states that:

*A critical element in the study of geometry for students in grades 9-12 is knowing how to judge, construct, and communicate proofs. Electronic technology enables students to explore geometric relationships dynamically, offers students visual feedback and measurement as they investigate geometric situations. Secondary school teachers face an important challenge in balancing this use of technology for exploring ideas and developing conjectures with the use of deductive reasoning and counter-example in establishing or refuting the validity of such conjectures. Students should be able to articulate for themselves why particular conclusions about geometric objects or relationships among objects are logically sound. It is not critical that students master any particular format for presenting proofs (such as two-column format). What is critical, however, is that students see the power of proof in establishing general claims (theorems) and that they are able to communicate their proofs effectively in writing.*

1. In the gspdemo folder there is a file /samples/sketches/pythag/behold.gsp. The sketch is a dynamic element in a proof by the Hindu mathematician Bhaskara of the Pythagorean Theorem. Construct a proof of the Pythagorean Theorem using the approach suggested in behold.gsp.
2. Prof. David Joyce has recreated the *Elements* in HTML format using Java to illustrate Euclid's proofs. This is a remarkable resource for anyone teaching Euclidean Geometry and is worth a thorough review. (My only concern in making this recommendation is that Prof. Joyce appears to be a committed opponent to many of the reforms advocated by the National Council of Teachers of Mathematics.) Euclid's proof of the Pythagorean theorem is found at <http://aleph0.clarku.edu/~djoyce/java/elements/bookI/propI47.html>. Compare and contrast the mathematics used by Bhaskara and Euclid.
3. Compare and contrast the two uses of technology. Which use do you prefer? Why?
4. Compose a 500 word response to the following question: "How may the Geometers Sketchpad and other technologies be used to facilitate the discovery and formalization of proof?" That is, once a relationship has been discovered, how may you use technology to facilitate discovery of the underlying facts and logical connections that collectively constitute a proof? What shifts in perspective and/or purpose must occur for the student?

## GROUP TASK #6

The following WWW sites provide a systematic introduction to fractal geometry at the middle school level.

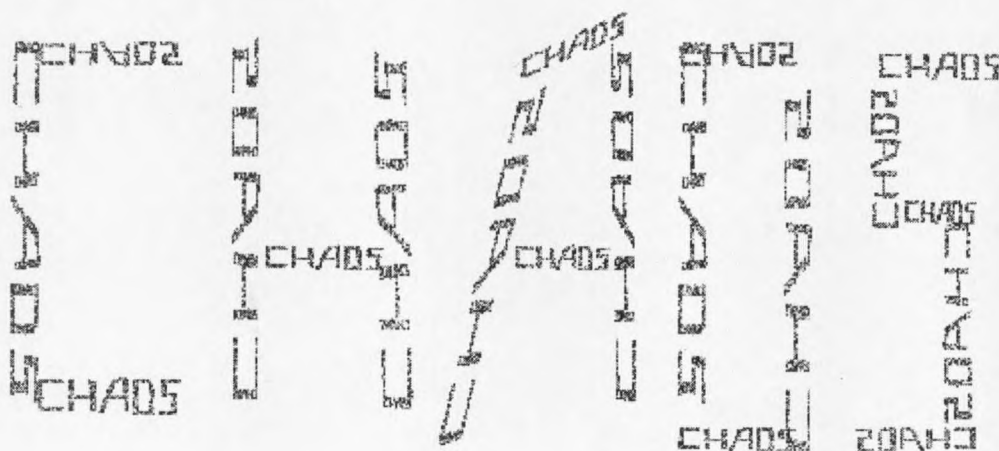
- <http://math.rice.edu/~lanius/frac/>
- <http://www.shodor.org/interactive/lessons/frac1.html>
- Summarize the content and approach taken in these materials and discuss the prerequisite mathematical concepts and skills that middle school students need in order to succeed with these lessons.

These WWW sites provide an introduction to Iterated Function Systems (IFS), a topic more suited to high school or college students.

- [http://campus.northpark.edu/math/courses/Math\\_1030/WebBook/MatrixGeometry/AFine/index.html](http://campus.northpark.edu/math/courses/Math_1030/WebBook/MatrixGeometry/AFine/index.html)
- <http://www.cs.rice.edu/~jeffh/fract/index.html>
- <http://www.williams.edu/go/math/courses/Math300/ephiffs>
- <http://eci.ucsb.edu/~mikeski/mathdiv/attract.html>
- In your own words, describe Iterated Function Systems and discuss the prerequisite mathematical concepts and skills that high school students need in order to succeed with these lessons.

The following fractal is based on an IFS consisting of 19 mappings, one for each "stroke" involved in the writing of the block letter version of chaos.

- Create a similar fractal based on the letters MATH (12 strokes) or MSU (12 strokes). List each linear transformation as a matrix and create the fractal using EphsIFS (above). Attach a copy to your MSUlink group report



**GROUP TASK #7**

1. Using the Geometers Sketchpad, investigate Peurcellier's Cell (peurcell.gsp) and explain its operation in terms of the transformation of inversion.
2. Discuss the concept of invariance as it applies to the transformation of inversion.
3. The Reuleaux Triangle is an interesting geometric novelty. Using the attached Sketchpad files and the following WWW sites, investigate Reuleaux Triangles and curves of constant width  
<http://www.nas.com/~kunkel/reuleaux.htm>  
<http://www.ics.uci.edu/~eppstein/junkyard/reuleaux.html>  
[http://www.cut-the-knot.com/do\\_you\\_know/cwidth.html](http://www.cut-the-knot.com/do_you_know/cwidth.html)

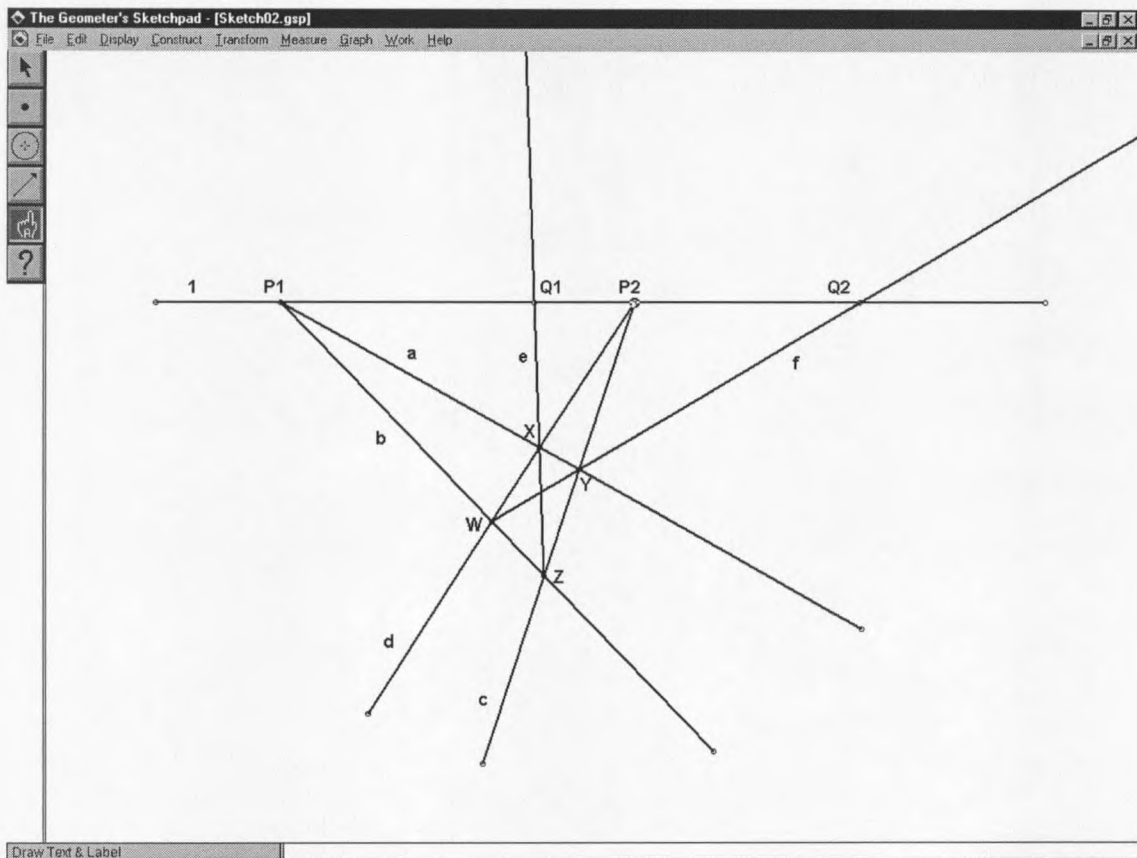
Using the Geometers Sketchpad, design a different curve of constant width and explain the basis for the construction. If possible, create and save the curve on the ntrigue server in your group folder. Label the file GT7.

<http://ntrigue.math.montana.edu:8080/gskp.htm>

**GROUP TASK #8**

Group task #8 is based on pp. 23-25 in Thomas. Your goal is to

- Investigate the relationship between the complete quadrangle WXYZ and points P1, Q1, P2, Q2 on line 1 shown below (See #1 below) and
- Show that P1, Q1, P2, and Q2 are in harmonic relationship (See #2 below)

**"Harmonic" - 1**

- Terms in arithmetic progression are separated by a common difference:  
1    2    3    4    5    ...
- Terms in harmonic progression are reciprocals of terms in arithmetic progression:  
1/1    1/2    1/3    1/4    1/5    ...

"Harmonic" - 2

|   |    |    |
|---|----|----|
| P | P1 | P2 |
|---|----|----|

$\mu = PP1/PP2$  is the **algebraic ratio** in which point P divides segment P1P2

|                  |            |            |    |
|------------------|------------|------------|----|
| $\mu_1 \delta_1$ | $\delta_1$ | $\delta_2$ |    |
| P1               | Q1         | P2         | Q2 |

$$\mu_1 = Q1P1/Q1P2$$

$$\mu_2 = Q2P1/Q2P2$$

Q1 and Q2 separate P1 and P2 **harmonically** if  $\mu_1 = -\mu_2$

1. Is the second use of the term harmonic consistent with the first use? To answer this question, consider the differences between reciprocals of successive terms. If the differences are the same, the terms are in harmonic progression according to the first definition.
2. Coordinate geometry offers a familiar environment in which to show that the complete quadrangle divides line  $l$  harmonically. Use the following notations and approach in making your case.
  - Let P1 correspond to (0,0) with P2 to the right on the x-axis  
Lines  $a, b, c, d$  with slopes  $a, b, c, d$ .  
[Write the equation of each line]
  - Points of intersection  
[Find the points of intersection W, X, Y, Z]
  - Lines  $e$  and  $f$  that intersect line  $l$  in points Q1 and Q2  
[Determine the intersections of lines  $e$  and  $f$  with line  $l$ ]
  - Differences in segment reciprocals  
[Determine the segment lengths and differences]
  - Show that the segments are in harmonic progression.

**GROUP TASK #9**

Figures 1 and 2 show a canyon system on Mars. Points A, B, C, D, and E are marked in both images. Your task is to:

1. Find the location of point X in the white, rectangular region of Figure 2 using the paper strip technique discussed in Thomas pp. 92-93; and
2. Thoroughly explain the mathematical basis of the paper strip technique and your solution to this problem.



Figure 1

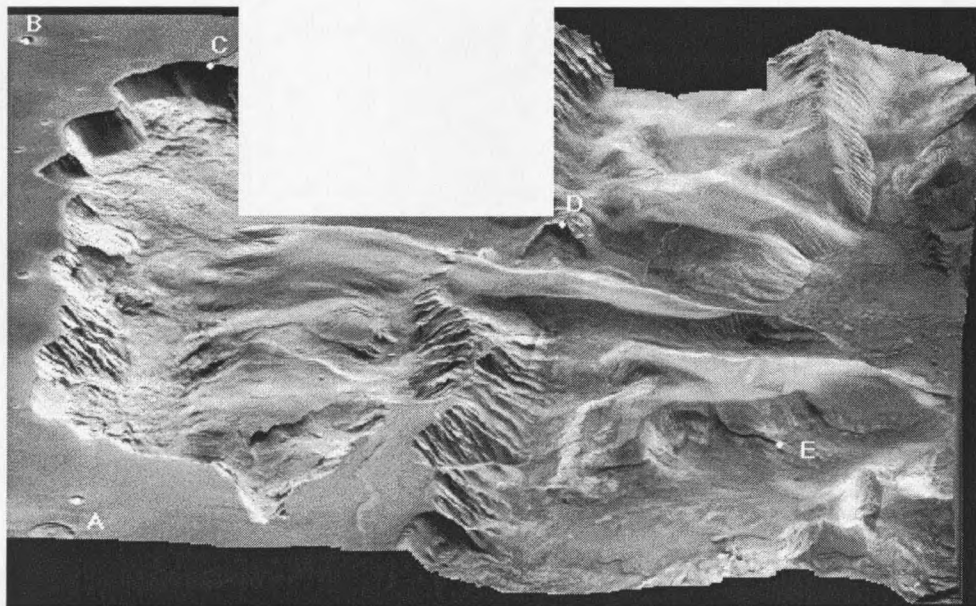


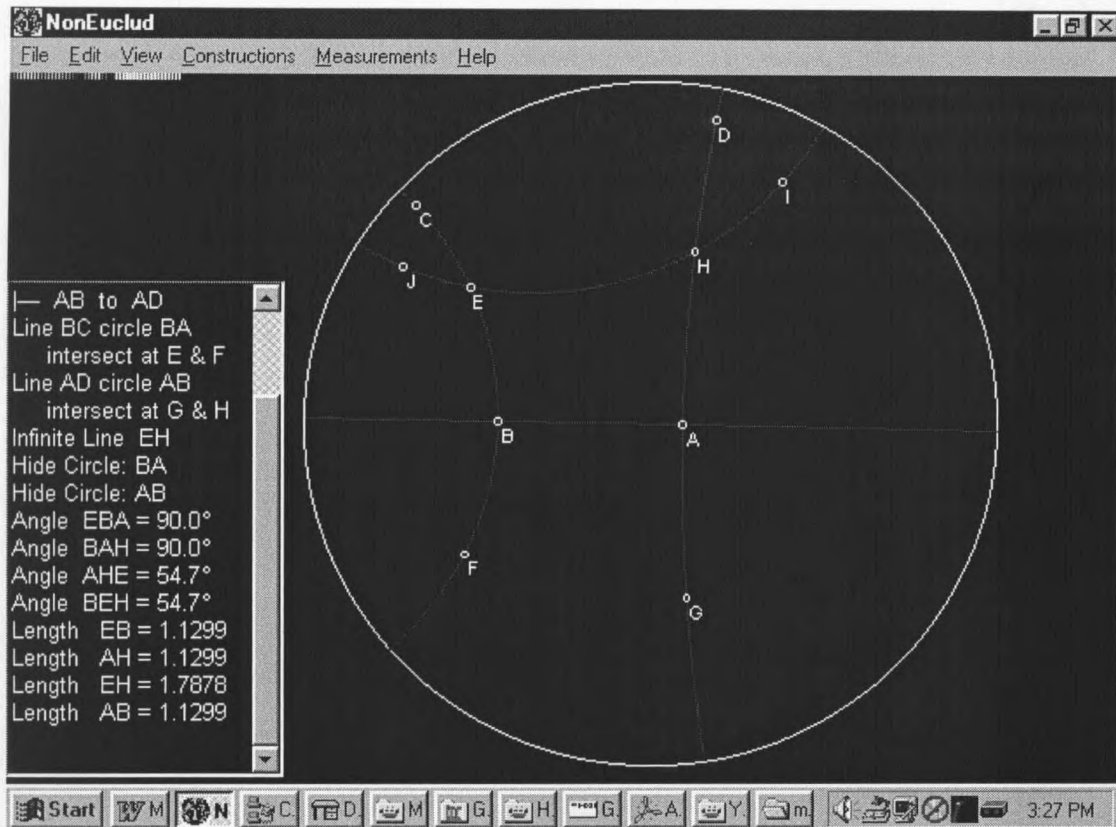
Figure 2

**GROUP TASK #10**

Choose three of the following five conjectures to work on for this group task. For each of the three, determine if it is a true statement or a false statement in hyperbolic geometry. Support your choice by providing an example (or counterexample) using Non Euclid. Also, if you believe a statement to be true, describe the steps you took to determine this.

- 1) If two triangles are similar, they must be congruent.
- 2) There exists a parallelogram with exactly one right angle.
- 3) Equilateral triangles do not exist.
- 4) Given  $\triangle ABC$ , if  $\overline{AB} \cong \overline{AC}$ , then  $\angle B \cong \angle C$ .
- 5) Vertical angles are congruent.

## GROUP TASK #11



- I. Using the labeling shown above, prove that in a Saccheri quadrilateral
  1. The summit angles are acute and congruent
  2. The summit is longer than the base
- II. For any hyperbolic triangle, prove that the sum of the angles is less than  $180^\circ$ .

**APPENDIX C**

**THE COURSE SYLLABUS**

(note: this syllabus was altered slightly throughout the course at the discretion of the instructor).

### Syllabus

#### Math 527 3 Semester Credits

#### Geometry for Teachers January 19 - April 30, 1999

|                                                                                                         |                                                                                                                                                                                                     |
|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| David A. Thomas<br>Department of Mathematical Sciences<br>Montana State University<br>Bozeman, MT 59717 | Phone (406) 994-5341<br>Fax (406) 994-1789<br><a href="mailto:Dave@math.montana.edu">Dave@math.montana.edu</a><br><a href="http://www.math.montana.edu/~dave">http://www.math.montana.edu/~dave</a> |
|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

### ABOUT THIS COURSE

Math 527 is a 15 week-long distance education course intended for K-12 mathematics teachers pursuing Masters of Science degrees in mathematics education at Montana State University. The course is delivered using a combination of mailed textbooks/materials and WWW-based distance education technologies. Students should plan to spend approximately 10 hours per week on course assignments and activities, including on-line discussions. Individuals unable to sustain this level of involvement should not enroll. Individuals with limited computer and/or Internet experience are cautioned that technical difficulties routinely encountered in the installation and operation of course software and communications technologies may occur to such an extent that on-site technical assistance is necessary. Locating and paying for such assistance is entirely the responsibility of the student. In order to identify and resolve technical difficulties before they cause serious instructional problems, students are urged to download, install and test all necessary technologies prior to the beginning of instruction.

**TEXTS** (Shipped to students with other course materials by the instructor)

*Modern Geometries, Fifth Edition* by James R. Smart, Brooks/Cole, ISBN/ISSN: 0-534-35188-3

*Active Geometry* by David A. Thomas, Brooks/Cole, ISBN/ISSN: 0-534-34485-2

### COMMUNICATIONS

All course-related discussions are conducted using First Class Client, an Internet-based communications tool mailed to students with other course materials. Regular, meaningful participation in on-line discussion is required of all students.

Quizzes and/or examinations reflecting the content of the textbook readings, homework, and directed activities will be posted here in PDF format. Students must download and save each quiz or examination, then print a hard copy using Adobe Acrobat Reader. Completed quizzes and/or examinations must be faxed to the instructor as specified in each document.

**GRADES**

2 Exams @ 100 pts = 200.

12 Group Tasks (GT) @ 10 pts = 120

4 Lesson Plans (LP) @ 20 pts = 80

Total points possible = 400      A- = 360, B- = 320, C- = 280, D- = 240

**WEEKLY AGENDA**

| Week    | Ch | Topic(s)                                             | Sample Performance Goals                                                                                                                                                                                                                                                                                                                                                              | Assignments                                                                                     |
|---------|----|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| 1/19/99 |    | Getting Started                                      | Download, install and test the <u>software and data files</u> used in the course                                                                                                                                                                                                                                                                                                      | <u>Mac</u> users<br>checksheet<br><u>PC</u> users<br>checksheet                                 |
| 1/25/99 | 2  | Transformation<br>Geometry<br><br>GT #1              | Given a set of transformation matrices, and the vertices of an "object" triangle, <ul style="list-style-type: none"> <li>Describe the features of each transformation</li> <li>Find the "image" of the triangle under a given composition of matrices</li> <li>Demonstrate all of this using the PC program Animate</li> <li>Use the TI-92 for matrix algebra calculations</li> </ul> | Smart:<br>2.3 11<br><br>2.4 10, 15,<br>18, 21, 25<br><br>Thomas:<br>42-47                       |
| 2/1/99  | 2  | Transformation<br>Geometry<br><br>GT #2<br><br>LP #1 | Create a lesson plan on some aspect of transformation geometry. Assume a 50 minute class period and appropriate technology for all students <ul style="list-style-type: none"> <li>Specify a grade level</li> <li>What instructional goals would you set?</li> <li>What technologies would you use?</li> <li>What assessment strategies?</li> </ul>                                   | Smart:<br>2.5 1, 7, 15,<br>17, 23<br><br>2.6 12, 13,<br>14, 19<br><br>2.7 5-7, 9,<br>12, 19, 20 |

|         |   |                                     |                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                            |
|---------|---|-------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| 2/8/99  | 4 | Euclidean Geometry<br><br>GT #3     | <p>Review the NCTM Standards and the current literature with regard to Euclidean Geometry.</p> <ul style="list-style-type: none"> <li>• What arguments can you advance supporting the introduction of Euclidean geometry at the junior high level?</li> <li>• At the senior high level?</li> <li>• What content do you consider appropriate at each level?</li> </ul>                                      | <p>Smart:<br/>4.1 1-7, 27</p> <p>4.2 2, 5, 6</p> <p>4.3 1-5, 15</p> <p>Thomas:<br/>1-9</p> |
| 2/15/99 | 4 | Euclidean Geometry<br><br>GT #4     | <p>Compare and contrast the features of Nine-Point Circles for specified triangles.</p>                                                                                                                                                                                                                                                                                                                    | <p>Smart:<br/>4.4 1-6, 9</p> <p>4.5 1, 3-5, 11</p> <p>4.6 1-6</p> <p>Thomas:<br/>13-18</p> |
| 2/22/99 | 4 | Symmetry<br><br>GT #5<br><br>LP # 2 | <p>Create tessellations, friezes, and wallpapers with specified features.</p> <p>Create a lesson plan on tessellations, friezes, or wallpapers. Assume a 50 minute class period and appropriate technology for all students.</p> <ul style="list-style-type: none"> <li>• Specify a grade level.</li> <li>• What instructional goals would you set?</li> <li>• What technologies would you use?</li> </ul> | <p>Thomas:<br/>52-70</p>                                                                   |

|        |   |                                                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                        |
|--------|---|--------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| 3/1/99 | 2 | <p>Fractal Geometry</p> <p>GT #6</p> <p>Exam #1</p>          | <p>Given a single similarity transformation,</p> <ul style="list-style-type: none"> <li>• Iterate the transformation several times on a given segment</li> <li>• Find an expression for the length of the curve in the n-th iteration</li> <li>• Find the fractal dimension of the self-similar curve</li> </ul> <p>Given a set of contractive affine maps and a given square,</p> <ul style="list-style-type: none"> <li>• Iterate the transformation several times on the given square</li> <li>• Find expressions for the area in the n-th iteration</li> <li>• Find the fractal dimension of the self-similar "strange attractor"</li> </ul> <p>Review the NCTM Standards and the current literature with regard to fractal geometry.</p> <ul style="list-style-type: none"> <li>• What arguments can you advance supporting the introduction of fractal geometry at the junior high level?</li> <li>• At the senior high level?</li> </ul> | <p>Smart:<br/>2.8 1-3, 8, 11; 13, 17</p> <p>2.9 2, 3, 4, 7, 8</p> <p>2.10 1</p> <p>Thomas:<br/>102-118</p>                             |
| 3/8/99 | 6 | <p>Transformation of Inversion</p> <p>GT #7</p> <p>LP #3</p> | <p>Create a lesson plan on some aspect of fractal geometry. Assume a 50 minute class period and appropriate technology for all students.</p> <ul style="list-style-type: none"> <li>• Specify a grade level.</li> <li>• What instructional goals would you set?</li> <li>• What technologies would you use?</li> <li>• What assessment strategies?</li> </ul> <p>Using the Geometers Sketchpad, investigate Peurcellier's Cell and explain its operation in terms of the transformation of inversion.</p> <p>Discuss the concept of invariance as it applies to the transformation of inversion.</p>                                                                                                                                                                                                                                                                                                                                            | <p>Smart:<br/>6.1 1-10, 16, 18-21</p> <p>6.2 1-3, 7-9, 14</p> <p>6.3 1, 9, 13, 16, 20</p> <p>6.4 5, 7, 16</p> <p>Thomas:<br/>71-74</p> |

|         |   |                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                       |
|---------|---|------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| 3/15/99 | 7 | Projective Geometry<br><br>GT #8               | <p>Review the NCTM Standards and the current literature with regard to projective and 3-dimensional geometry.</p> <ul style="list-style-type: none"> <li>What arguments can you advance supporting the introduction of projective at the junior high level?</li> <li>At the senior high level?</li> <li>What content do you consider appropriate for each?</li> </ul>                                                                       | <p>Smart:<br/>7.1 6-17<br/><br/>7.2 2, 11-15<br/><br/>7.3 1-10, 16, 17<br/><br/>Thomas:<br/>79-87</p> |
| 3/22/99 | 7 | Projective Geometry<br><br>GT #9               | <p>Explain the mathematical basis for the cartographer's "paper strip technique."</p> <p>Given a perspective view of a scene, find a given point in a different perspective of the same scene using the paper strip technique.</p>                                                                                                                                                                                                          | <p>Smart:<br/>7.4 1, 4, 5, 6, 9<br/><br/>7.5 2, 3, 4, 11<br/><br/>Thomas:<br/>88-93</p>               |
| 3/29/99 | 7 | Projective Geometry<br><br>GT #10<br><br>LP #4 | <p>Create a ray-traced 3-D movie using the National Educational Supercomputer.</p> <p>Create a lesson plan on some aspect of projective geometry. Assume a 50 minute class period and appropriate technology for all students.</p> <ul style="list-style-type: none"> <li>Specify a grade level.</li> <li>What instructional goals would you set?</li> <li>What technologies would you use?</li> <li>What assessment strategies?</li> </ul> | <p>Smart:<br/>7.6 1-3<br/><br/>7.7 1, 2, 4, 8-10, 11<br/><br/>Thomas:<br/>94-101</p>                  |

|         |   |                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                    |
|---------|---|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| 4/5/99  | 9 | Hyperbolic Geometry<br><br>GT #11 | Compare and contrast Euclidean and Hyperbolic Geometry                                                                                                                                                                                                                                                                                                                                                                                                            | Smart:<br>9.1 22-27<br><br>9.2 2, 3, 5, 7-15<br><br>9.3 1-7, 15<br><br>Thomas:<br>28-32            |
| 4/12/99 | 9 | Hyperbolic Geometry<br><br>GT #12 | Review the NCTM Standards and the current literature with regard to non-Euclidean geometry. <ul style="list-style-type: none"> <li>What arguments can you advance supporting the introduction of projective at the junior high level?</li> <li>At the senior high level?</li> <li>What content do you consider appropriate for each?</li> </ul> <p>Discuss the "reality" of the geometries studied in this course and their applications in the "real" world.</p> | Smart:<br>9.4 1, 2, 4-7, 10, 12<br><br>9.5 1-4, 16<br><br>9.6 1, 2, 5-7, 9<br><br>Thomas:<br>32-35 |
| 4/19/99 |   | Term Projects                     | Finish term projects                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                    |
| 4/26/99 |   | Exam #2                           | Present term projects                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                    |

**APPENDIX D**

**CRITERIA USED TO RANK GROUP TASKS**

Each group task was ranked on 2-5 different content criteria, technology use, and whether the group followed the correct format in creating their solution. Each content criterion item was judged separately. The group that met the criterion item best received a score of 1. The group that met the criterion item second best would receive a score of 2, third best group would score a 3, and the fourth best (i.e. the worst) group would receive a score of 4. Then the next criterion item was judged on the same scale, and so forth until all content criteria had been judged. These items were then summed to arrive at a total content score. The group with the lowest total content score would receive a ranking of 1, the second lowest score a ranking of 2, and so on. Ties in this total score were broken by a further analysis on the content criteria to determine which of the tied groups did better overall on the content criteria.

The use of technology was ranked according to a four-level hierarchical scale: Insightful, Appropriate, Correct, and Other (an explanation of what each means can be found on page 70-71). The scale used to determine the ranking for technology was the same scale used for content criterion. The group that was judged to make best use of the technology received a rank of 1, the second best group a score of 2, and so on. If ties existed (for example, if two groups were rated "Appropriate") the group task was further analyzed in order to determine which of the tied groups made better overall use of the technology.

The content criteria rank was added to the ranking for use of technology and the format score (0 for yes, 1 for no) to arrive at a total score. The group with the lowest total score would be given the rank of 1 for the task; the group with the second lowest total score would be given the rank of 2; and so on. These are the rankings that are found in the table in Appendix F titled "Ranking of Group Tasks". The ranking given to the groups in the content criteria section broke ties in the total score.

### **Group Task 1:**

#### **Content:**

- Composition of matrices shows both indicated and final product
- Underlying mathematics was explained
- Illustration

#### **Technology:**

- Insightful
- Appropriate
- Correct
- Other

#### **Format (yes or no)**

**Group Task 2:**

Content:

- Found transformation matrix  $T$
- Found invariant points and lines
- Geometric description of the transformation was complete
- Animate movie using the transformation matrix  $T$

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 3:**

Content:

- Conjectures about segments complete
- Conjectures about angles complete
- Conjectures about areas complete
- Proof

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 4:**

Content:

- Report on the URL
- Demonstrated that the 9-point circle and the circumference are related by dilation

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 5:**

Content:

- Proof
- Compared and contrasted the mathematics of the two proofs
- Compared and contrasted the technology used in the two proofs
- Essay was complete and informative

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 6:**

Content

- Summarized the content and approach taken at the URL sites
- Described IFS (iterated fractal systems) and prerequisite concepts and skills
- Created an IFS listing each linear transformation
- Attached a printout of the fractal

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 7:**

Content:

- Explained Peucellier's Cell in terms of the transformation of inversion
- Discussed the concept of invariance as it related to inversion
- Constructed a curve of constant width and explained the basis for the construction

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 8:**

Content:

- Completely answered the question: "Is the second use of the term harmonic consistent with the first?"
- Demonstrated that the quadrangle divides the line harmonically

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 9:**

Content:

- Found the location of point X using the paper strip technique
- Explained the mathematical basis for the paper strip technique

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 10**

Content:

In Hyperbolic Geometry proved or disproved:

- If two triangles are similar, they must be congruent
- There exists a parallelogram with exactly one right angle
- Equilateral triangles do not exist
- Given  $\triangle ABC$ , if  $\overline{AB} \cong \overline{AC}$ , then  $\angle B \cong \angle C$
- Vertical angles are congruent

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**Group Task 11:**

Content:

For a Saccheri quadrilateral:

- Proved that the summit angles are congruent
- Proved that the summit angles are acute
- Proved that the summit is longer than the base
- Proved that the sum of the angles of any hyperbolic triangle is less than 180 degrees

Technology:

- Insightful
- Appropriate
- Correct
- Other

Format: (yes or no)

**APPENDIX E:**

**EXAMPLE GROUP PROBLEM-SOLVING TASKS**

## RED GROUP TASK #5

**The Geometer's Sketchpad - [Behold.gsp]**

File Edit Display Construct Transform Measure Graph Work Help

**D. Bennett 3.11.95**  
 The figure on the left is shown in a manuscript by Hindu mathematician Bhaskara accompanied only by the word "Behold!" The figure is also found in the Chou-peï, an ancient Chinese classic of unknown date, but perhaps pre-dating Pythagoras. Drag point D or Double-click the ANIMATE button to show different triangles.

**Left Diagram:** A square with side length  $c$ . It is divided into four right triangles and a central square. The area is labeled  $c^2 =$ .

**Right Diagram:** A large square with side length  $b+a$ . It is divided into a green square of side  $b-a$ , two light blue triangles, and two purple triangles. The area is labeled  $b^2 + a^2$ .

You can also show the five pieces add up to  $c$  squared by using a little algebra. **Animate**

This sketch illustrates the proof from the activity "Behold" in the book *Pythagoras Plugged In*, published by Key Curriculum Press.

Select Polygon 2"()

Start Finished - winload Network FirstClass Intranet Cl... gspdemo The Geometer's... 10:01 AM

For the right picture we figured out the areas of all of the parts. From the picture there are two squares: one with side length  $b$  and one with side length  $a$ . This is how we can subtract or add  $b-a$  to these sides in the proof below.

1. The area of the green square is  $(b-a)^2 = b^2 - 2ab + a^2$
2. The area of the left light blue triangle is  $0.5(b)(b-(b-a)) = 0.5ba$
3. The other light blue triangle would be the same thing.
4. The area of the bottom purple triangle is  $0.5(a)(a+(b-a)) = 0.5ab$
5. The other purple triangle is the same.

When you add up all of these areas you get  $b^2 - 2ab + a^2 + ab + ba = a^2 + b^2$

To find the area of the left picture we used the same measurements and got the same answer but we also knew that it was a square with side length  $c$ , therefore the area is  $c^2$

Therefore  $a^2 + b^2 = c^2$

**PROBLEM STATEMENT:** First, using the approach suggested in behold.gsp, construct a proof of Pythagorean's Theorem. Second, compare and contrast the mathematics used by Bhaskara in "Behold!" and Prof. David Joyce in his illustration of Euclid's proof. Third, compare and contrast the two types of technology used. Finally, compose a 500 word response to the following question: "How may the Geometers Sketchpad and other technologies be used to facilitate the discovery and formalization of proofs?"

**KEY MATHEMATICAL CONCEPTS:** To complete the Pythagorean proof we used the following concepts: area of a triangle, area of square. To compare and contrast the mathematics used by Bhaskara and Euclid we used the following concepts: constructing altitudes as heights of triangles, comparing similar triangles by side-angle-side and comparing areas of triangle to areas of parallelograms.

**STRATEGIC PLAN AND/OR APPROACH:** First we formulated a proof using Bhaskara's method and then compared it to Euclid's method. We then compared the uses of technology and responded to the given question.

**USE OF TECHNOLOGY:** Geometers Sketchpad, Internet site in Java

**PRINCIPAL FINDINGS OR RESULTS:** See attached proof.

Compare/contrast mathematics: Bhaskara used areas rectangles, triangles and squares to prove the Pythagorean Theorem. Euclid used congruent triangles and related areas of triangle to parallelograms.

Compare/contrast technologies: our group preferred The Geometers Sketchpad. Although The Java image could be moved around we felt limited because it was such a small area. We also disliked the Java image because we were not able to take measurements to find relationships.

**NECESSARY GRAPHICS AND/OR OTHER FILES:** See attached proof.

**DISCUSSION AND/OR EXPLANATION (500 word response):**

"How may the Geometers Sketchpad and other technologies be used to facilitate the discovery and formalization of a proof?"

Geometers Sketchpad and other technologies are very useful in facilitating the discovery and formalization of a proof. As our group found in attempting a proof for Pythagorean's Theorem, GSP gives us a great advantage. The program allowed us to investigate and form conjectures for our proof in our own way and at our own pace.

First, we'll address how technologies facilitate the discovery of a proof. Geometers Sketchpad can provide a very useful model for students to work with. As they move this model through a series of translations and modifications, students can discover that certain points and lines may be invariant. They can discover relationships between areas and objects as the Sketchpad allows them to manipulate at their own will. This

active participation in the discovery of certain relationships aids the student in forming conjectures about objects that lead to formal proof. It gives them an instantaneous way to answer any questions they may have about the validity or visualization of proofs. Being able to be in control and receive instant results helps student with their mathematical insight and confidence in their own mathematical abilities.

Second, we'll address how technologies such as Geometers Sketchpad and the TI-92 facilitate formalization of a proof. It seems that proofs can be a source of much confusion for many students. Even those students who are able to follow formats and crank out written proofs at a reasonable rate often miss what's going on behind the scenes. GSP and other programs have tremendous power to help formalize proof for all types of students. A very helpful tool is a teacher made model of a particular proof illustrated with an object for student manipulation. With this tool students can explore the deeper meaning of a proof. As we discovered in group task number five. There is much more to Pythagorean's Theorem than is evident in the simple formula given to us in high school. GSP and the Java base file on the Internet helped us discover these concepts quickly yet thoroughly. Considering the time it may have taken for the first proof to be formulated these technologies provide use with a very powerful and useful tool.

The Geometers Sketchpad and other technologies are more helpful in the discovery of conjectures. Once the conjectures or theorems have been found these technologies can be used to visualize the underlying mathematics. Since you cannot use these technologies in a proof: for example "angle  $a = \text{angle } b$ " "By the Geometers Sketchpad." This does not work. The key to using technologies in proofs is to let them do the busy work; such as constructing the diagrams in Bhaskara's proof of the Pythagorean theorem. In the days of Euclid a proof of a geometrical object could only be drawn with the assistance of a compass and a straight edge. In modern times a student can use a technology, for a second perspective, such as a visual geometric interpretation to explain an algebraic expression. In constructing geometrical figures these technologies can be very useful. They can construct perfect circles, right triangles, and squares. Technologies can also help the student to break down a large problem into smaller problems. These smaller problems are more comprehensible for the students, which will help them to solve the larger problem. Another important aspect of creating geometrical proofs is the consideration of invariant points and lines. These technologies can identify or create invariant points and lines.

The TI-92 was extremely helpful in proofs. It can solve large complicated equations and matrices in general without using page after page of algebra. If you are teaching and trying to get the students to visualize a proof you can put the TI-92 on an overhead projector and describe a graphical representation of an object.

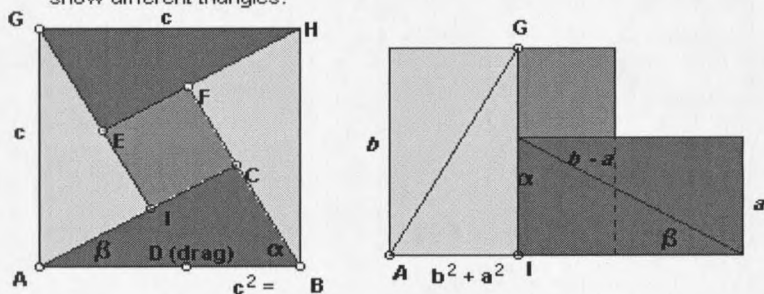
## BLUE GROUP TASK #5

**Problem Statement:**

1. Construct a proof of the Pythagorean Theorem using the approach suggested in behold.gsp.

**Proof:****D. Bennett 3.11.95**

The figure on the left is shown in a manuscript by Hindu mathematician Bhaskara accompanied only by the word "Behold!" The figure is also found in the Chóu-peí, an ancient Chinese classic of unknown date, but perhaps pre-dating Pythagoras. Drag point D or Double-click the ANIMATE button to show different triangles.



You can also show the five pieces add up to  $c$  squared by using a little algebra.

 **Animate**

This sketch illustrates the proof from the activity "Behold" in the book *Pythagoras Plugged In*, published by Key Curriculum Press.

$$m\angle GAI = 60.5^\circ$$

$$m\angle CAB = 29.5^\circ$$

$$m\angle GAD + m\angle CAB = 90.0^\circ$$

Given: The triangles in the sketches are right triangles

Proof that all triangles in the sketch are congruent.

By definition of square:

$$\angle CAB = \angle ABH = \angle BHG = \angle HGA = 90^\circ$$

$$90^\circ + (90^\circ - \beta) + \alpha = 180^\circ$$

$$180^\circ - \beta + \alpha = 180^\circ$$

$$-\beta + \alpha = 0^\circ$$

$$\alpha = \beta$$

$ABC \cong GAB \cong HGE \cong BHF$  by Side-Angle-Angle

Show that the five pieces add up to  $c$  squared.

Four right triangles and square within the object makeup the large square.  
These objects are then rearranged in the right sketch in the picture above.

Area of a square is side squared:

$$c * c = c^2$$

Area of a rectangle is width times length.

$$a * b + a * b + (b - a) * (b - a) =$$

$$2ab + (b - a)^2 =$$

$$2ab + b^2 - 2ab + a^2 =$$

$$b^2 + a^2 = c^2$$

2. Compare and contrast the mathematics used by Bhaskara and Euclid.

**Answer:**

Bhaskara's approach involved a little geometry to prove that the triangles were congruent. The rest of his approach is mainly algebraic. Dr. Joyce used all geometry based on Euclid's postulates and construction to prove the Pythagorean theorem.

3. Compare and contrast the two uses of technology. Which use do you prefer? Why?

All of us preferred the Geometer's Sketchpad. We felt it was easier to gather data on the objects to prove the Pythagorean Theorem. If we wanted to measure the segment lengths or angles to back up our proof, we could. The Java Applet allowed us to manipulate the object but did not allow us to measure findings.

**Answer:**

4. Compose a 500-word response to the following question: "how may the Geometers Sketchpad and other technologies be used to facilitate the discovery and formalization of proof?" That is, once a relationship has been discovered, how may you use technology to facilitate discovery of the underlying facts and logical connections that collectively constitute a proof? What shifts in perspective and/or purpose must occur for the student?

**Answer:**

Geometers Sketchpad and other technologies can be used in the modern classroom to facilitate the discovery and the formalization of geometric proofs in several ways. First, Geometers Sketchpad and the other technologies allow students to dynamically study geometry in an interactive way that has never been available to

students in the past. Throughout the course of using the technologies, students are encouraged to manipulate the geometric objects to discover as many relationships or characteristics of the object as possible. Technologies like the Geometers Sketchpad allow students to measure line segments, angles, areas, and ratios of these measurements to show congruencies or similarities. Once this is done, the SketchPad drawing can be manipulated to allow the student to investigate whether or not there are any variant or invariant properties of the drawn object. For example, in the current task it was possible to reflect and translate one of the triangles to coincide with another one, which was a proof of the congruency by using the technology. With these technologies it is easy for the student to show that the discovered relationship is applicable to all relevant cases. Once the relationship is discovered, then the student must search for the reasons why the discovered relationship exists in order to prove the relationship. These technologies can also be used to find further relationships that may be used to solidify the proof of the initial geometric property. Students are able to actively investigate the underlying geometric properties to discover the concrete characteristics and connections that collectively constitute a geometric proof. Another benefit of these technologies is that the students can test the geometric proof for themselves and discover the properties and limitations of the proof. The technologies also give the student the ability to test their own ideas, intuition, theories and the consequences of the proof, which has not been available to students until recently. This testing or investigation process can also lead the students to the consequences and applications of the proof. In effect, the technologies bring a "visual meaning" to the written geometric proof, and thereby allowing the student to have a visual basis to the written proof.

Geometers Sketchpad and other technologies also facilitate the process of geometric discovery and proof building by stimulating interest in the students. These technologies increase the student's interest in Geometry through the associated "hands-on" activities, which corrects a common problem with the typical proof building process. While other technologies may be limited to some of the investigation (such as measurements or construction of an object), students will still have hands on interaction with the objects in question. Properties students may visualize through this interaction may allow them to come up with some conclusions about the object in question. Computer technologies are a familiar and appropriate medium to teach the principals of geometry to Jr. High and High School students, since most have access to some form of computing technology. This technology can be the overriding factor in the student's ability to build the bridge from the visual geometric properties to conceptual geometry, which the student will need later in their mathematical education. This shift from visual geometry to conceptual geometry is a large hurdle for the student to cross and is the difference between just completing the proof and understanding the underlying geometric properties. Also these technologies change the focus of the student from reading their textbook and then writing a 2-column proof to actively discovering the underlying characteristics of the proof with the technology, thereby allowing the student to build geometric intuition and the foundation for completing the proof. The "hands on" experience no longer engages the teacher to a type of lecture format where students take notes directly to what is being taught. This type of teaching relies on rote memorization

by a student. The cognitive level of the student may not be lasting for further areas of study using the traditional approach. The student must be involved with the discovery process in order for them to assimilate and apply what is being taught in classes today into other areas. The student's perspective in using this type of interaction is similar to those that discovered the postulates and theorems that apply.

## GREEN GROUP TASK #5

### 1. PROOF FOR #5

Area of Triangle  $abc = \frac{1}{2} ab = \frac{ab}{2}$   
 In Picture 1

$$\begin{aligned}
 c^2 &= \left( \frac{ab}{2} \right) + (b-a)^2 \\
 &= \frac{4ab}{2} + (b-a)^2 \\
 &= 2ab + (b-a)(b-a) \\
 &= 2ab + b^2 - ba - ab + a^2 \\
 &= 2ab + b^2 - (ba + ab) + a^2 \\
 &= 2ab + b^2 - 2ba + a^2 = a^2 + b^2 \\
 c^2 &= a^2 + b^2
 \end{aligned}$$

### 2. Euclid vs. Bhaskara

After looking at both methods of proving the Pythagorean Theorem, our group decided that we preferred Bhaskara's method rather than Euclid's.

Bhaskara uses the idea that the sum of the three rectangles with areas  $ab$ ,  $ab$ , and  $(b-a)^2$  add up to  $c^2$ . Euclid uses the idea of building three squares to prove the theorems and uses congruent triangles and areas. He builds three triangles, one off of each side of the right triangle where the sum of the two areas of the smaller squares is the area of the larger square. He uses this to show that  $AC^2 + BA^2 = BC^2$ .

Both methods use the notion of areas of squares to prove the theorems, but Bhaskara's method is a lot clearer and more straight forward. Euclid's method is messy and confusing. It seems as if he spends a lot of time and effort trying to explain what is obvious and does so much extra work that doesn't seem to be needed. On the other hand, Bhaskara just shows what is needed and nothing more.

### 3. Java applet vs. Geometer's Sketchpad

We seem to prefer the Geometer's Sketchpad that displayed the mathematic Bhaskara over the Java applet that showed Joyce's proof. With both uses technology we could move the picture and get an idea of what was happening with the sketchpad we could do more. We were able to analyze the segments, which were the  $a$ ,  $b$ , and  $c$  in the Pythagorean theorem, and see how they were relating when the picture moved. We could also look at the specific areas see how they related to each other; specifically the square in the middle relating triangle areas

### 4. Essay

Using the Geometer's Sketchpad and other technologies can be very useful in facilitating the discovery and formalization of proof. It is very important to remember, though that the relationship must be discovered first, then looked at from the different types of technology.

It is a well known fact that students remember and become interested in things if they have an ownership of them. That is if they have discovered these facts on their own or proved statements to be false. Therefore, uses of technology can help the students to discover relationships on their own, by moving the angles etc., and it becomes more valuable to them. Relating to this, students become more interested in tasks if they understand them more thoroughly. Using these technologies, they are moving the parts around, they are seeing for themselves what is happening in the proof that they have either already written or just seen. Using these technologies may even find the students looking at connections other than the ones that they are trying to prove. This is very important in striking an interest into the students for them to look into geometry more deeply and with much more curiosity.

If we were to look directly at the types of technology, the students are able to use fixed points and move other points around (Geometer's Sketchpad). They can see the angles change or stay the same likewise the segment measures. Using a specific example, if one were to look at the triangle's angles adding up to 180 degrees. Most students know this fact but they can see it firsthand by using the Geometer's Sketchpad and moving any point on the triangle. The Geometer's Sketchpad allows them to construct these simple objects or more complex objects more easily which helps the students save time from having to construct them themselves.

Another important use of the technologies is the simple idea that students are then using both inductive and deductive reasoning. This is the shift in perspective that the

student must take. When they look at the proof without the computer, they are using their deductive reasoning whereas when they are discovering truths or falsities, they are using inductive reasoning. Their purpose when they use the computer is to look at why it is happening or why their formal proof should not be so. This also pushes the student to be able to fit a proof to other situations. For example, if the student is looking into a computer formalization, they are learning to fit the proof to other situations. This extends to other situations where they need to adapt math concepts to fit a variety of situations.

Technologies can be used to facilitate the discovery and formalization of proof as long as they are used as facilitators. It is important for students to use the technology as a type of discovery tool that allows them to 'see' what they are doing. The student's perspective must change from the deductive to the inductive stage of reasoning, though.

## YELLOW GROUP TASK #5

### Problem Statement:

- Construct a proof of the Pythagorean Theorem using the approach demonstrated in the manuscript of Bhaskara titled simply "Behold".
- Compare and contrast the mathematics used by Bhaskara and Euclid.
- Compare and contrast the two uses of technology, Geometer's Sketchpad vs WWW.
- Compose a 500 word response to the following question: "How may the Geometer's Sketchpad and other technologies be used to facilitate the discovery and formalization of proof?"

### Key Mathematical Concepts:

- The discovery and formalization of proof of the Pythagorean Theorem aided by Bhaskara and Euclidian approaches and modern technology.

### Strategic Plan/Approach:

- Examine the approaches towards proof of the Pythagorean Theorem as presented by Bhaskara and Euclid, comparing the mathematics used in each, then construct a proof modeled after Bhaskara's manuscript "Behold", which uses the reconstruction of areas. This will be accomplished with the aid of the Geometer's Sketchpad and a version of "Behold" which allows for manipulation of the geometric figures, which construct the original area of  $c^2$ .

### Use of Technology:

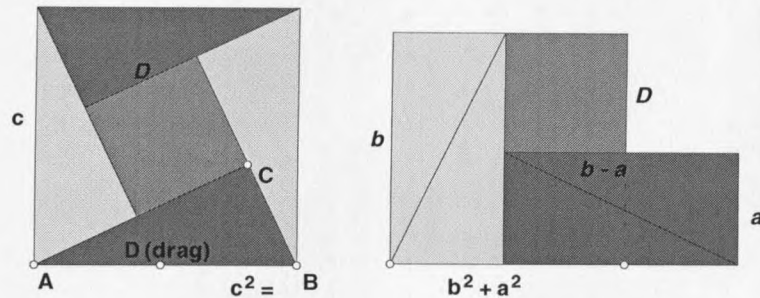
- Both the Geometer's Sketchpad and the internet/WWW were used in examination of differing styles of formalization of proof of the Pythagorean Theorem.

### Principle Findings:

- Through the reconstruction of geometric figures, composing the original object of  $c^2$  (composed of a square formed by 4 identical original right triangles), we discovered, since areas remain invariant during the transformations of translation and rotation, the sum of areas of the objects that are transformed are equal to that of the original object  $c^2$ .
- Construct a proof of the Pythagorean Theorem using the approach demonstrated in the manuscript of Bhaskara titled simply "Behold".

- The first three proofs which follow are based on the Bhaskara approach as per the manuscript "Behold". The latter two proofs are based on Euclid's approach as per Propositions 47 and X.33 and are presented in contrast to Bhaskara.

D. Bennett 3.11.95



- PROOF #1: Based on the Bhaskara approach.

1) Proof:

- Original right triangle ABC
- Sides are abc
- Because of right triangle ABC, putting side AB adjacent to side BC creates a right angle. Doing this in such a fashion as to put 4 triangles ABC together with the c side to the exterior produces  $c^2$  with a square block (D) in the middle. We know that it is square because the sides are constructed from the legs of the right triangles.

Note: The two rectangles that are found in the re-assembly are formed by placing 2 triangles ABC together with their hypotenuses adjacent to each other. By theorem, diagonals of rectangles bisect the rectangle into 2 congruent right triangles. Doing this twice forms the two rectangles and together with block D constitute the entire area of  $c^2$

Re-assembly: Areas remain invariant under translation/rotation.

- $b = a + \text{side of block D}$
- $a = b - \text{side of block D}$
- Side of block D =  $b - a$

Reconstruction:

- Square 1:  $b \times (a + b - a) = b \times b = b^2$
- Square 2:  $a \times (b - (b - a)) = a \times (b - b + a) = a \times a = a^2$

Result:        Square 1 =  $b^2$   
                     Square 2 =  $a^2$

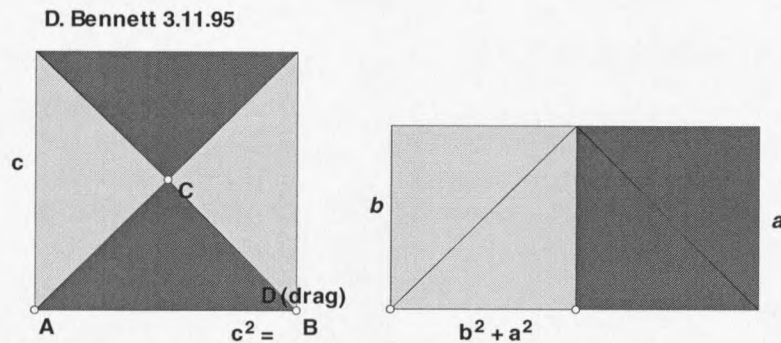
Therefore since all areas have remained invariant:  $c^2 = a^2 + b^2$

➤ PROOF #2: Based on the Bhaskara approach.

The initial triangle has short side  $a$ , medium side  $b$ , and hypotenuse  $c$ . A square is formed of side  $c$  and  $c$ , therefore its area is  $c^2$ . Its interior is subdivided into four triangles and a small square. Re-assembly produces two squares, one of side  $b$  and the other of side  $a$ . Since areas remain invariant under translation or rotation, the second figure has the same area as the first, which is  $a^2 + b^2$ .

The area of the second figure can be found by summing the area of four triangles and one square. So,  $A_{\text{total}} = 4 \cdot A_{\text{triangles}} + A_{\text{square}} = 4 \cdot \frac{1}{2} ba + (b-a)(b-a) = 2ab + b^2 - 2ab + a^2 = b^2 + a^2$ . Therefore,  $a^2 + b^2 = c^2$ .

➤ PROOF #3: This is a special case of the Bhaskara approach where the original triangle is an isosceles right triangle and  $c^2$  is composed only of a composite of 4 original ABC triangles.



1) Proof: (special case)

- a) Original isosceles right triangle ABC
- b) Sides are  $abc$

Note: The two squares that are found in the re-assembly, are formed by placing 2 triangles ABC together with their hypotenuses adjacent. By theorem, diagonals of rectangles bisect the rectangle into 2 congruent right triangles. Doing this twice, forms the two rectangles (squares in this case) and constitutes the entire area of  $c^2$ .

Re-assembly: Areas remain invariant under translation/rotation.

- a)  $b \times b = b^2$
- b)  $a \times a = a^2$

Reconstruction:

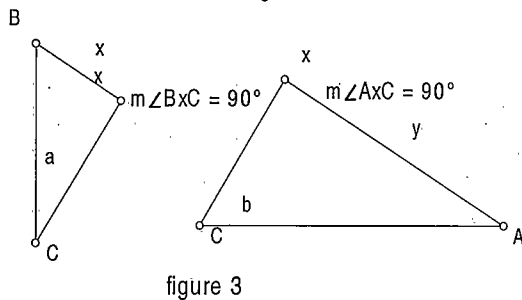
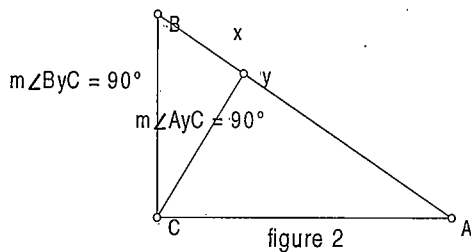
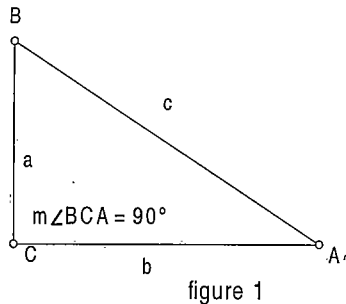
- c) Square 1:  $b \times b = b^2$
- d) Square 2:  $a \times a = a^2$

Result: Square 1 =  $b^2$

$$\text{Square } 2 = a^2$$

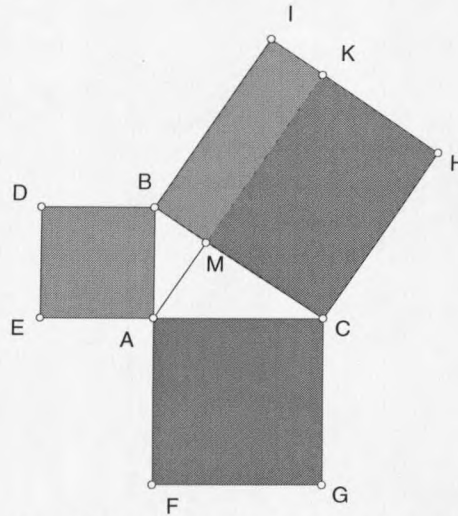
Therefore since all areas have remained invariant  $c^2 = a^2 + b^2$

➤ PROOF #4: In contrast, here is a proof based on a Euclidian approach of similar triangles.



1. Given Triangle ABC ,figure # 1
2. Draw a line from the right angle perpendicular to the hypotenuse. Fig . 2
3. This divides the hypotenuse into 2 segments. We will call these segments x and y
4. This line also divides the triangle into two small right triangles. Fig.3
5. All three triangles are similar so the ratios of corresponding sides are proportional
6. Therefore the following ratios are equivalent  
 $x/a = a/c$  and  $y/b = b/c$
7. In the first proportion multiply both sides of the equation by a this will yield  
 $x = a^2 / c$
8. In the second proportion multiply both sides of the equation by b and this will yield  
 $y = b^2 / c$
9. Substitute  $a^2/c$  and  $b^2 / c$  into the equation
10.  $c = x + y$  ( these are the two parts of c)  
this yields
11.  $c = (a^2 + b^2) / c$   
multiply both sides by c
12. this yield  $c^2 = a^2 + b^2$

➤ PROOF #5: This is another contrasting proof based on an Euclidean approach.



**Given: Right triangle ABC, where angle BAC is right and AM is an altitude.**  
Squares are drawn on each side of triangle ABC.

Triangles ABM, CBA, and CAM are similar, for pairwise they share two angles in common.. Since corresponding parts of similar triangles are proportional, then the following proportions hold:

$CB/BA = BA/BM$ , so crossmultiplying yeilds  $BA^2 = CB*BM$   
(The product  $CB*BM$  is rectangle area BMKI)

$BC/AC = AC*CM$ , so crossmultiplying yeilds  $AC^2 = BC*CM$   
(The product  $BC*CM$  is rectangle area MCHK)

So, adding the left sides together and the right sides together of the above equations gives

$BA^2 + AC^2 = CB*BM + BC*CM$   
(The sum and product  $CB*BM + BC*CM$  is equivalent to square BCHI, which has an area of  $BC^2$ .)

Finally, by substitution  $BA^2 + AC^2 = BC^2$ .

- Compare and contrast the mathematics used by Bhaskara and Euclid:  
Although the math involved by Euclid is understood, it seems that he has used a complex approach which involves a base understanding of math postulates far beyond that of Bhaskara. The original sketch of Euclid visually seems simplistic, with right triangle and squares formed on each side. Applying the math to allow us to establish the proof of  $c^2 = a^2 + b^2$  centers on confusion and would probably be the same for first time geometers. In contrast, Bhaskara is like playing with blocks. It is easy to visualize  $c^2$  and why there is a square block in the middle. With some very simple algebra, wa-la, we acquire  $a^2$  and  $b^2$  which we know came from  $c^2$ , since areas are invariant under translation and rotation.
- Compare and contrast the two uses of technology, Geometer's Sketchpad vs WWW.  
The use of www, which allows links to incorporate the math being used, is quite convenient. The references are directly accessible and allow for quick confirmation.  
The GSP on the other hand, is much more visually appealing. It is easy to see the re-assembly of objects and by manipulating the objects, we see with little effort how the objects may change shape but in corresponding fashion.
- Compose a 500 word response to the following question: "How may the Geometer's Sketchpad and other technologies be used to facilitate the discovery and formalization of proof?"

Students of all grade levels are continually perplexed by the nature of mathematical proof. However, we as educators feel that the National Council of Teachers of Mathematics is correct in placing a call for more exploration of proof in the mathematics classroom. This task is not an easy one, but we feel that the use of technologies such as The Geometer's Sketchpad will help students facilitate the discovery and formalization of mathematical proof.

We do not contest the importance of teaching mathematical proof because its benefits reach far and beyond the realm of the mathematics classroom. There is a problem, though. How do we introduce the notion of proof to students who do not have the natural ability to conceptualize it? The introduction of visual aides often helps students to achieve a greater understanding than they could achieve with words alone. However, the ease of creating visual displays for every problem requiring proof can be cumbersome and seemingly impossible without the aid of technology. Programs such as The Geometer's Sketchpad allow students to visualize the mathematics behind the proof. Educators and parents should not worry that this will "take away" from the learning of mathematics, rather it will complement it and foster mathematical growth.

By providing students with a visual understanding of the mathematics involved in a proof through the use of technologies like The Geometer's Sketchpad, we as educators are allowing all students the benefits of a mathematical base. From this foundation, students can more readily formulate mathematical proofs. The use of technology serves as a tool in the case, but does not do the work for the students. The students are still expected to formulate the reasons and the verbiage for their proofs. This allows students who do not have an abstract understanding of mathematics to create mathematical proofs and understand the underlying mathematics as well. This is achieved simply by allowing them a visual aid that they can manipulate.

The importance of "hands on" work with mathematical proof is growing, as is a demand for higher level thinking skills. We feel that the use of technology in the classroom helps cultivate both of these aspects of the mathematics classroom. The students are given an opportunity to visualize and manipulate objects to prove theorems and ideas. The technology allows them to achieve a sense of understanding of higher level mathematical ideas without the "grunt work" getting in the way. This is not to dispute the importance of learning how to do the "grunt work," rather it is to show that there is a time and place for cumbersome mathematical work. When students get bogged down with the arithmetic and algebra of a problem before they understand it, it becomes increasingly difficult for them to accomplish their goals. With the advent of technology, we are giving those students the ability to understand mathematics before they go about the technicalities. This allows for a greater understanding of the entire mathematics process and where each piece fits.

We as educators should remain open and receptive to the use of technology in our classrooms. This is especially important to the facilitation of growth in the area of mathematics known as "proof." By providing students with this tool, we are providing them with the key to the realm of mathematical thought.

**APPENDIX F**

**DATA TABLES**

The following tables are presented as incidental information. These tables are listed in order to give a more complete and accurate picture of the data discovered during this study. The first table lists the raw scores given to each of the groups for the group tasks by the instructor. For example, on group task #1, the Red Group received a score of 100, the Blue Group received a score of 95, the Green Group received a score of 90, and the Yellow Group received a score of 95.

Table 24. Group task scores.

| Group Tasks Scores |     |      |       |        |
|--------------------|-----|------|-------|--------|
| Task               | Red | Blue | Green | Yellow |
| 1                  | 100 | 95   | 90    | 95     |
| 2                  | 95  | 95   | 90    | 98     |
| 3                  | 90  | 85   | 90    | 100    |
| 4                  | 100 | 100  | 100   | 100    |
| 5                  | 85  | 80   | 85    | 95     |
| 6                  | 95  | 100  | 90    | 100    |
| 7                  | 95  | 90   | 90    | 95     |
| 8                  | 100 | 100  | 100   | 100    |
| 9                  | 90  | 100  | 95    | 100    |
| 10                 | 100 | 100  | 100   | 100    |
| 11                 | 100 | 100  | 100   | 100    |

The Table 25 on the next page lists the rankings given by the researcher for the group tasks, based on the criteria in Appendix D. The range is from 1 to 4, with 4 being the highest possible score. For example on group task #1, the Blue Group was given the highest rating, the Yellow Group the second highest rating, the Red Group the third highest rating, and the Green Group the fourth highest (or lowest) rating.

Table 25. Ranking of group tasks.

| Task | Ranking of Group Tasks |      |       |        |
|------|------------------------|------|-------|--------|
|      | Red                    | Blue | Green | Yellow |
| 1    | 2                      | 4    | 1     | 3      |
| 2    | 2                      | 3    | 1     | 4      |
| 3    | 3                      | 1    | 2     | 4      |
| 4    | 2                      | 1    | 3     | 4      |
| 5    | 1                      | 2    | 3     | 4      |
| 6    | 1                      | 4    | 2     | 3      |
| 7    | 1                      | 3    | 2     | 4      |
| 8    | 1                      | 4    | 2     | 3      |
| 9    | 3                      | 4    | 1     | 2      |
| 10   | 1                      | 3    | 2     | 4      |
| 11   | 2                      | 1    | 4     | 3      |

Table 26 lists the raw data collected from the administration of the Computer Attitude Scale to eleven of the thirteen on-campus students at the beginning of the semester. Each subscale (Anxiety, Confidence, Liking, and Usefulness) had 10 questions. The highest possible score for any subscale is 40. In general, the higher the score, the more positive the attitude towards computers.

Table 26. Computer Attitude Scale survey results.

| Name       | Anxiety | Confidence | Liking | Usefulness | Total |
|------------|---------|------------|--------|------------|-------|
| Student 1  | 40      | 38         | 37     | 37         | 152   |
| Student 2  | 25      | 27         | 30     | 38         | 120   |
| Student 3  | 34      | 35         | 34     | 39         | 142   |
| Student 4  | 22      | 22         | 24     | 27         | 95    |
| Student 5  | 40      | 40         | 40     | 40         | 160   |
| Student 6  | 37      | 35         | 34     | 39         | 145   |
| Student 7  | 38      | 38         | 34     | 35         | 145   |
| Student 8  | 30      | 24         | 25     | 37         | 116   |
| Student 9  | 39      | 39         | 37     | 39         | 154   |
| Student 10 | 37      | 34         | 26     | 33         | 130   |
| Student 11 | 33      | 33         | 27     | 36         | 129   |

Table 27 sums up the individual and group message data: the total messages scored, the total messages sent (this includes messages sent by each individual and group that were not given a score), the total score of all the messages and the average phase level.

Table 27. Individual and group message data.

|                        |        | Total    |          |       |         |
|------------------------|--------|----------|----------|-------|---------|
| INDIVIDUAL TOTALS      |        | Scored   | Total    | Total |         |
| Name:                  | Group: | Messages | Messages | Score | Average |
| Red 1                  | Red    | 6        | 6        | 15    | 2.50    |
| Red 2                  | Red    | 20       | 20       | 38    | 1.90    |
| Red 3                  | Red    | 8        | 9        | 15    | 1.88    |
| Red 4                  | Red    | 6        | 6        | 12    | 2.00    |
| Total for Red Group    |        | 40       | 41       | 80    | 2.00    |
|                        |        |          |          |       |         |
| Blue 1                 | Blue   | 30       | 33       | 67    | 2.23    |
| Blue 2                 | Blue   | 28       | 28       | 69    | 2.46    |
| Blue 3                 | Blue   | 35       | 36       | 79    | 2.26    |
| Blue 4                 | Blue   | 36       | 41       | 94    | 2.61    |
| Blue 5                 | Blue   | 56       | 62       | 151   | 2.70    |
| Total for Blue Group   |        | 185      | 200      | 460   | 2.49    |
|                        |        |          |          |       |         |
| Green 1                | Green  | 31       | 34       | 77    | 2.48    |
| Green 2                | Green  | 25       | 26       | 61    | 2.44    |
| Green 3                | Green  | 8        | 9        | 21    | 2.63    |
| Green 4                | Green  | 10       | 14       | 24    | 2.40    |
| Total for Green Group  |        | 74       | 83       | 183   | 2.47    |
|                        |        |          |          |       |         |
| Yellow 1               | Yellow | 68       | 77       | 164   | 2.41    |
| Yellow 2               | Yellow | 49       | 52       | 90    | 1.84    |
| Yellow 3               | Yellow | 47       | 54       | 105   | 2.23    |
| Yellow 4               | Yellow | 109      | 122      | 235   | 2.16    |
| Yellow 5               | Yellow | 109      | 121      | 238   | 2.18    |
| Total for Yellow Group |        | 382      | 426      | 832   | 2.18    |

**APPENDIX G**

**PERMISSION FORMS**

### Computer Attitude Survey (Loyd, Gressard)

The survey is scored according to the following:

For questions 1, 3, 4, 6, 9, 11, 12, 14, 16, 17, 19, 22, 25, 27, 28, 30, 33, 35, 36, 38  
(Strongly Agree = 4, Slightly Agree = 3, Slightly Disagree = 2, Strongly Disagree = 1)

For questions 2, 5, 7, 8, 10, 13, 15, 18, 20, 21, 23, 24, 26, 29, 31, 32, 34, 37, 39, 40  
(Strongly Agree = 1, Slightly Agree = 2, Slightly Disagree = 3, Strongly Disagree = 4)

The questions are coded so that the higher the score, the more positive the attitude.

Four subscores can also be obtained from the questions.

|             |                                      |
|-------------|--------------------------------------|
| Anxiety:    | 1, 5, 9, 13, 17, 21, 25, 29, 33, 37  |
| Confidence: | 2, 6, 10, 14, 18, 22, 26, 30, 34, 38 |
| Liking:     | 3, 7, 11, 15, 19, 23, 27, 31, 35, 39 |
| Usefulness: | 4, 8, 12, 16, 20, 24, 28, 32, 36, 40 |

Again, higher scores correspond to more positive attitude, e.g., a higher confidence score means more confidence and a higher anxiety score means less anxiety.

Permission is granted for use of this scale. In any publication arising from its use, please be sure to credit the authors, Brenda H. Loyd and Clarice P. Gressard.

Thanks for your interest. Best wishes.

Doug Loyd

Date: Fri, 24 Mar 2000 12:53:04 -0700 (MST)  
From: "Charlotte Nirmalani Gunawardena (Lani)" <lan@unm.edu>  
Subject: Re: Interaction Analysis Model  
To: Brian Beaudrie <Brian.Beaudrie@NAU.EDU>

Brian,

I contacted my co-authors and we do not have any problems with you publishing our model in your thesis as long as the proper references are made to the article, authors and journal. You might want to check with the journal editor, Dr. Seidman whether he would give you permission to publish the model as it is as the journal has the copyright on it.

We would very much like to read your findings when you complete the thesis and hope that you would share the results with us.

Best wishes  
Lani Gunawardena

Date: Thu, 30 Mar 2000 09:58:48 -0500  
From: Robert Seidman <rseidman@minerva.nhc.edu>  
Subject: Re: Interaction Analysis Model  
To: Brian Beaudrie <Brian.Beaudrie@NAU.EDU>  
Cc: baywood <baywood@baywood.com>  
X-Mailer: Mozilla 4.7 [en] (Win98; U)  
X-Accept-Language: en,pdf

Brian: Congratulations on your thesis! I have no problem with your request as long as the article and journal are cited. I am forwarding this to the Journal's publisher, **Stewart Cohen**, so that he may send you official permission.

Best wishes. Bob

Date: Mon, 03 Apr 2000 13:11:11 -0400  
From: Baywood <baywood@baywood.com>  
To: BRIAN.BEAUDRIE@NAU.EDU  
Cc: RSEIDMAN@MINERVA.NHC.EDU  
Subject: Permission Request

April 3, 2000

To: Brian Beaudrie  
From: Julie Krempa  
Subject: Permission Request

Dear Brian:

Dr. Robert Seidman has forwarded your permission request.

We are pleased to grant permission for you to use Figure 2 titled "Interaction Analysis Model for examining social construction of knowledge in computer conferencing" (page 414) created by Charlotte Gunawardena, Constance Lowe and Terry Anderson published in the Journal of Educational Computing Research, Volume 17: 4, (1997) from the article on pages 397-431 titled, "Analysis of a Global Online Debate and the Development of an Interaction Analysis Model for Examining Social Construction of Knowledge in Computer Conferencing" by Charlotte N. Gunawardena, Ph.D., Constance A. Lowe, M.A. and Terry Anderson, Ph.D. in your dissertation.

Please be sure to cite the material used properly.

Sincerely,

Julie Krempa  
Rights & Permissions

MONTANA STATE UNIVERSITY - BOZEMAN



3 1762 10335655 4